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MAJOR DAVID BATES DOUGLASS.

A Biographical Sketch.*

David Bates Douglass, son of Nathaniel and Sarah Bates Douglass, was born at Pompton, New Jersey, March 21, 1790.

His early edueation was carefully and ably superintended by his mother until he was prepared to enter Yale College, from which he graduated with high honors in 1813.

From Yale College young Douglass went directly to the Military Academy at West Point, and soon entered the military service of the United States as an officer of the Engineer Corps. In 1814 he was detailed with his command in the Northwestern campaign of that year. He performed brilliant service during the siege of Fort Erie, for which he received the commendation of General Gaines, and was further rewarded by promotion to a captain by brevet.

About 1816, Captain Douglass received the appointment of Assistant Professor of Natural Philosophy in the Military Academy, and the succeeding 15 years were spent by him in active official duties at West Point and in civil engineering.

In the practice of this latter profession, he made, in 1826, surveys and estimates for a canal from Conneaut Lake to Lake Erie. The same year he made surveys for the location of the Upper Delaware canal. A revision of the surveys of the Sandy and Beaver canal, of Ohio, followed by an examination and survey of the vicinity of Philadelphia, to establish the terminus of the Pennsylvania Railroad, were professional services performed about the same period.

In November, 1828, Major Douglass made an examination of the line of the Morris canal, of New Jersey, with reference to the employment of inclined planes instead of locks. His subsequent report and plans led to a professional engagement in the service of the Company, and his resignation of his chair at the Military Academy. This occurred in 1831.

The inclined planes were soon brought into successful operation, and were justly regarded as an important engineering achievement.

In 1832 he entered the New York University, its first Professor of Natural Philosophy; but finding his professorship to interfere with his engineering pursuits, he relinquished this position after one year's duty, but was borne on the roll of the institution as Professor of Civil Engineering and Architecture, and during the year of 1836 and 1837 he delivered a course of 80 lectures on these subjects.

In 1833 he was called upon to survey the route for the Brooklyn and Jamaica Railroad on Long Island, which he completed in the winter of that year.

An act was passed by the New York Legislature, February, 1833, authorizing surveys and estimates for supplying the city of New York with water. Imme-

* Lives and Works of Civil and Military Engineers of America, by Chas B. Stuart, C. E. New York: D. Van Nostrand.

diately after the passage of this Act, the Board of Water Commissioners appointed Major Douglass and Canvass White, engineers. But the professional duties of Mr. White in the State of New Jersey preventing him from making the examination desired by the commissioners, the whole duty devolved upon Major Douglass, who completed the preliminary surveys in November of that year, and made his report soon thereafter; regarding which the commissioners, in their report of November, 1833, say:

"For a more particular and detailed description of the surveys, and other important information on the subject, the commissioners beg leave to refer to the able and lucid report of the engineer, Major D. B. Douglass, hereunto annexed."

In the report referred to, Major Douglass recommended the use of the Croton river and its tributaries to be conveyed to the city by an enclosed stone aqueduct, and estimated the length of the same from the confluence to the receiving reservoir at Manhattanville at 37 miles, and from the latter to the distributing reservoir, 5½ miles. The report states that "the structure of masonry has been adopted instead of iron pipes on the ground of its superiority in point of economy, durability, and efficiency."

Also, "the crossing of the Harlem river is proposed to be effected by means of an aqueduct bridge, 1,180 ft. long from abutment to abutment, consisting of 9 semicircular arches. The height of the structure, from the water-line of the river to the water-line of the aqueduct, would be 126 ft., exclusive of the hydraulic foundations, which would be from 10 ft. to 20 ft. more. A structure adapted to these dimensions would be, of course, a work of considerable labor and expense, but by no means of paramount difficulty in either respect."

A feasible and durable plan for supplying the city of New York with water in abundance for not only its population at the time, but for the anticipated rapid increase in the future, had, since the year 1820, agitated the public mind, and various methods had been devised, and plans reported upon, none of which, at this period, proved acceptable to the citizens.

Major Douglass at once comprehended the importance of the undertaking, both as to the health and its bearing upon the future growth of the city, and earnestly devoted himself to the successful accomplishment of the work.

The first investigations were directed to finding an abundant and unfailing supply of pure, wholesome water, and at an elevation that would allow of its flow into the city by its own gravitation, and with a head that would supply the upper stories of the buildings; and that could be used from the hydrants for the extinguishment of fires.

With these purposes in view, Major Douglass commenced his explorations and surveys in May, 1833, and in the following month he reported examinations of "all the chief tributaries of the Croton river and several of the remarkable reservoirs from which they derive their supply; generalizing, meanwhile, the slope of the left bank with reference to the various routes of exit in the direction of the city. This is indeed a wonderful country for water, whether we regard the abundance or the purity of its fountains; and the intervening obstacles appear less formidable than I had supposed them to be."

On the completion of the preliminary surveys, and an estimate of cost, Major Douglass submitted a report to the Board of Commissioners, and the feasibility of the plan was so clearly shown, that the sanction of the Legislature was readily obtained in an Act of May, 1834, for proceeding with the construction of the work. Douglass was appointed Chief Engineer.

As early as October, 1835, the surveys necessary for the location of the Croton dam were completed, but in opposition to the judgment of the chief engineer, the Commissioners changed the location to Garretson's Mill, with a graduation of 40 ft. as its height.

Throughout his term of service Major Douglass found great difficulty in maintaining proper discipline in his corps of engineers, from the limited power with which the Commissioners invested him. They were unwilling to admit the necessity of an engineering department, and while Major Douglass fully realized the magnitude of the undertaking, the Board regarded it as little more than an extended job of plain masonry, that might easily be constructed upon very economical principles.

There existed widely different views of economy and discipline between the first Board of Commissioners and the chief

engineer, which finally led to a change that was universally regretted by the numerous friends of Major Douglass.

In October, 1836, he was removed from the charge which his experience and high scientific attainments so ably qualified him to prosecute to completion. His surveys, plans, drawings, and reports were submitted to the Board, and by them adopted, and the construction of the work passed into other hands.

The various surmises and rumors upon the abrupt and unexpected discharge of Major Douglass by the Board of Commissioners, in many instances prejudicial to his reputation, and from which he would not undertake to exonerate himself, and although urged by several members of the Board to do so, is fully explained in the following letter to one of the Commissioners, in 1840:

"In addressing a few lines to you on the subject of the unpleasant controversy which occurred in 1835-6, I cannot think it will be necessary to say much in the way of vindicating myself.

"You did not indeed witness but a very small portion of the violence and overbearing of Mr. Allen's conduct to me, but enough must have been seen to assure you that it was wholly as involuntary as it certainly was free from personality on my part.

"Should you have any doubts on this point, they cannot but be removed when I assure you that, painful as the controversy was in itself, and disastrous as the consequences have been to me to be thus thrown out of employment suddenly and unexpectedly, at a time when all other resources were unavailable; to have a great work, the only one I had thought worthy of my ambition, taken out of my hands after being matured in all its most difficult features; my professional character—the capital on which I and many others depended for our daily bread—assailed,—to have experienced all this at the hands of Mr. Allen, while my friends were importuning me to write, and members of the Common Council urging me to furnish statements, yet I resisted all influences and published not a line.

"It would have been very easy to show the unsoundness of every allegation brought against me, either in the Commissioners' report or in the papers, from 1835 to the present time. I pledge myself to do this for you, or for the new Board, whenever you or they may desire it; but I abstain from doing it before the public, simply because I resolved that no consideration of a personal kind should induce me to do any thing to disturb or interrupt the progress of the great work. Let me beg you to consider the exceeding injustice of the assertion often made by Mr. Alleys and Mr. Allen, that I had been a partisan in opposition to the Water Commissioners. Had I been such a partisan these gentlemen would have heard from me in different style, but I have not been."

In 1837 and 1838, Major Douglass made an examination and report on the hydraulic power of the Monmouth Purchase; also a reconnoissance of the coal region of the Upper Potomac; and from 1837 to 1840, he was occupied in laying out the grounds of Greenwood Cemetery.

This beautiful locality was observed by him as highly appropriate to such a purpose, while engaged in the construction of the Brooklyn and Jamaica Railroad. These surveys, though they had no reference originally to this object, were incidentally applied to it in the public lectures which he was called upon to deliver in Brooklyn, about the period of 1835. The original cemetery comprised only 178 acres, the ground declining in some places to valleys of less than 20 ft. above tide water, and in others rising to hills of more than 200 ft. Mount Washington is 216 ft., being the most elevated ground in Kings County, and one of the highest points on Long Island. A heavy native growth of fine old forest trees suggested the name of "Greenwood" as appropriate for this cemetery. The artistic skill and classic taste of Major Douglass is beautifully illustrated in the laying out of this quiet and romantic home for the dead.

It contains 413 acres of hill and dale. Mount Auburn is beautiful, Laurel Hill has its charms, but none of the cemeteries of the country can compare with Greenwood in the wonderful grandeur of its views, its variety of landscape, and its extent.

The avenues extend for nearly 25 miles, and it has several hundred miles of walks and paths within its enclosure.

From 1839 about $5,000,000 had been received, and nearly all of it expended on

improvements. To grade the grounds, and lay out the avenues and walks was an immense work, and it has been continued through many years, not being entirely completed even now.

The principal entrance to Greenwood is on Fifth avenue, South Brooklyn; the gateway is a magnificent and costly structure of Gothic form, and constructed of the finest brown sandstone.

It is very large, and presents an imposing and massive appearance.

This gateway is probably the finest piece of architecture of its kind in this country.

In his letter of resignation to the Board of Trustees of Greenwood Cemetery, of which he was President, tendered in January, 1841, Major Douglass remarked: "The local organization and the laying out of the grounds is now essentially completed. To have left this in an imperfect and unfinished state would have incurred the loss of much previous labor. I have felt it imperative, therefore, to remain in office at all hazards until it was finished. It has been a work of much greater labor than I supposed when I commenced it. The extent as well as the varied features of the ground have called for long-continued, oft-repeated, and very careful study; and this I have given it, but with what effect cannot be seen until the design shall have been in some degree carried out by the opening of the avenue."

The immediate cause of Major Douglass's resignation was his acceptance of a call to the Presidency of Kenyon College, in Ohio.

Before leaving for his new charge he submitted the plans and drawings for the improvement of the cemetery grounds to the Board. Mr. J. A. Perry, of Brooklyn, writing upon the subject a year subseqnently, observed:

"Anything about Greenwood, and especially its long-desired success, would not be an uninteresting theme to its old and faithful friend. We are now opening our avenues through the forests, and they open most beautifully. Having, providentially it would seem, nothing to occupy my time since March last, I have devoted it all to Greenwood; delightful work, now that it is crowned with success, has it been. In June we propose to consecrate our grounds. It is but meet that one who has contributed so greatly to the establishment, and developed so admirably the beauties of Greenwood, as we delight in thinking you have done, should participate in the ceremonies of that occasion. Can you not be with us?"

Major Douglass replied as follows:

"Believe me, you could not have done me a greater favor than in thus communicating the future brightness of Greenwood. My own associations with it are as fondly cherished, and all my recollections of it as fresh as ever. How delighted would I be could I promise myself, with any degree of assurance, the pleasure you hold up to my view so temptingly, of joining you in the approaching consecration; but I fear it is impossible.

"I can realize how delightful a relief the Greenwood improvements must be to your mind. Pressed and borne down as I frequently was while there engaged, its associations were always vivifying and gladdening to me. Its deep shades and quiet retreats, its old oaks and green cedars, the umber foliage during its Indian summer, the setting sun from Mount Washington, its breezes and its flocks of birds—everything about it was unlike anything else in this world. I yearn to see them again. Indeed, everything about Brooklyn continues to interest me as much as ever. No lapse of time can efface the smallest of the recollections by which it is endeared to me."

The following letter from Professor Olmstead, of Yale College, to Rev. Malcolm Douglass, indicates the feelings of those with whom Major Douglass was early associated, and the deep interest his classmates manifested in his subsequent varied and brilliant career:

"I send herewith the interesting letter addressed by your honored father to his classmates at their thirty years' meeting, in 1843. It was read in the meeting, and listened to with lively interest, but with deep regret that the writer could not make one of our most delightful party. Professor Douglass was justly regarded as a member who had done great honor to his class, by his gallantry in the service of his country during the war of 1812, and by his eminence as a man of science, particularly by the great public works which he projected, several of which remain as

durable monuments of his genius and skill."

Major Douglass continued his association with Kenyon College until 1844, when he returned to the East, and occupied his time until 1848 in the active discharge of various duties, among which were the planning and laying out of the Albany Rural and of the Quebec Cemeteries; the survey of the Albany Water Works; the drainage and graduation of South Brooklyn; the planning a supporting wall for a portion of Brooklyn Heights; in examinations and reports upon the best method for supplying that city with water, and the laying out of the grounds of the New Brighton Association, of Staten Island. In 1848 he was called to the chair of mathematics at Geneva (now Hobart) College, which he accepted, although other propositions were laid before him with offers of greater compensation.

Major Douglass died at his residence in Geneva, New York, October 21st, 1849, from the effects of a paralytic stroke, at the age of 59 years. His remains were deposited at Geneva. After the lapse of little more than 12 months they were removed to the Greenwood Cemetery, in answer to a request based upon the following resolution by the Cemetery Board, December 2d, 1850, as follows: "*Resolved*, That two lots for the use of the family of the late Major Douglass be designated by the Standing Committee, and when the remains of Major Douglass are deposited therein, the said committee shall cause the lots to be suitably enclosed, and an appropriate monument to the memory of Major Douglass erected thereon." His remains now repose in that beautiful Necropolis, to the creation of which his admirable genius so largely contributed.

No monument to his memory has yet been erected there. At this period the only public memorial of his life and death is to be found in the large and richly stained monumental windows of the south aisle of Trinity Church, Geneva, upon which is traced the following inscription: "To the glory and praise of God. The children of the late David Bates Douglass, filled with affection for his memory, and with devout gratitude for his paternal precepts and Christian example, erect this memorial window."

Major Douglass in stature was several inches above the medium height, slender, but finely proportioned, with an energetic, earnest movement, and distinguished military presence.

His features, without being regular or handsome, were strongly marked and striking; his hair was dark, and his eyes black, large, and restless; his voice deep-toned and firm. With brilliant conversational powers he combined a manner of address, polished, quiet, and unostentatious. He was a favorite of the drawing-room and of the family circle.

Religious in his proclivities, he superintended with pious vigilance the education of his family. His two eldest sons were graduates of Kenyon College.

The eldest, Charles Edwards, was destined for the church. After graduating, he passed regularly through the University course at Trinity College, Hartford, Connecticut, and is now the Rector of St. Paul's Church, Windsor, Vermont.

From him many valuable papers were obtained and used in the preparation of this imperfect sketch of his distinguished and venerated father. The fourth son, Henry, after going partly through a college course, entered the U. S. Military Academy at West Point, and graduated in 1851. Major Douglass also left four daughters.

One might deem the years of Major Douglass comparatively few in number, and his death premature, but in glancing at the leading events of his life from his early graduation at Yale College to the period of his death, with the reflection that within the narrow limits of a biography of this nature, only the professional incidents could be recorded, he had lived long in useful mental exertion.

Every hour had been occupied in earnest labor for the cultivation of others, or in plans for the military defence or public improvements of his country. While Professor of Architecture of the University of the City of New York, the university buildings were constructed from his design, being the first introduction into this country of the Elizabethan style.

The following tribute to the peculiar qualities of Major Douglass as a teacher, and his character as a Christian, is from the sermon of the Rev. Dr. Hale, President of Hobart College, upon the death of Major Douglass, and coming from one who was so well qualified to judge, and who had been associated with him as a

teacher and a neighbor, gives it greater value and force :

"By the caste of his mind and the qualities of his heart, no less than by the extent of his attainments, he was fitted to be a teacher. He had a rare facility in acquiring knowledge and making himself master of it in all its broadest principles and minutest details; but it seemed to be his great pleasure and the peculiar tendency of his mind to impart it.

"He loved books, but if I may judge from my acquaintance with him, which was intimate, he was less a reader than a thinker. He looked reverently upon books—books which he desired and sought—and read them, not for amusement, but a serious occupation of the mind and heart. He read, therefore, not superficially, but intently, as he would have listened to the voice of a teacher in answer to earnest and important inquiries. He possessed great powers of analysis, which he exercised not in a captious or doubting spirit, but that he might better know and form the material whereon to exercise that faculty of his intellect which was more peculiarly his characteristic, the constructive talent.

"Hence, his views, his opinions, his aims, were all definite. Hence, the depth and clearness of his instruction. Hence, in conversation he was still the teacher, and without any of the forms of argument, his discourse, clear in its own light, was full of information."

NOTES ON FIRE-BRICKS.

By Lieut. G. E. GROVER.*

Fire-bricks are so named from their property of comparative infusibility when exposed to very high temperatures. I say *comparative*, because no known material seems to enjoy absolute immunity from decomposition under the attacks of unlimitedly intense heat. Even the nominally infusible substances (pure silica, alumina, lime, and magnesia ; the natural varieties of rotton-stone—a very aluminous silicate of alumina, decomposed from rock ; and the silicates of magnesia, talc, asbestos, steatite or soap-stone), have been known to succumb in the flame of an oxyhydrogen blowpipe, or between the poles of a galvanic battery.

It is, however, clearly unnecessary to discuss in this paper any materials but those practically obtainable in large quantities ; and of these the chief components in Great Britain are the so-called fire-clay, with the exception of the silicious Dinas *rock* in the Vale of Neath, Glamorganshire, to which fuller reference will be made hereafter. Clays proper are chemical compounds, occurring under different phases in numerous geological formations, and consisting of hydrated silicates of alumina, either alone or in combination with silicates of potash, soda, lime, magnesia, iron, manganese, etc. Though a sediment from water (being, in fact, decomposed rock, characterized by a very minute division of constituent particles), they are tough and plastic, differing from mud in these respects, as well as in the absence of vegetable and animal matters. The plasticity and tenacity of argillaceous earths are due to the prominence of the ingredient alumina (which has a strong affinity for water), and are diminished by the presence of iron, lime, and magnesia. Clays appear to be the result of the slow decomposition by water of felspar, or some similar material, containing either potassa or soda.

The so-called fire-clays owe their refractory properties to a variable absence —differing, that is to say, in different clays—of lime, oxide of iron, and the alkalies of magnesia, potassa and soda. In refractory bricks, formed of baked fire-clay, the silica may be considered as a passive ingredient, acting mechanically to prevent excessive contraction, whilst the alumina forms the cement which binds the particles together.

The following is a list of the usual constituents of fire-clay, with their respective chemical symbols :

Silica (or silicic acid)..... $Si O_2$
Alumina (or sesquioxide of aluminum)..... $Al O_3$
Peroxide (sesquioxide or red oxide) of iron..... $Fe_2 O_3$

* Extract from a paper presented to the Corps of Royal Engineers.

Lime (oxide of calcium)..... Ca O
Magnesia (oxide of magnesium)... Mg O
Potassa (oxide of potassium)..... K_2 O
Soda (oxide of sodium)..... Na_2 O

and the following table details, for the sake of example, their proportions found in chance samples of several well-known classes of English fire-brick.

	Silica.	Alumina	Peroxide of iron.	Lime.	Magnesia.	Potassa.	Soda.	Titanic acid.	Total.
Stourbridge	65.37	26.48	5.68	.28	.33	1.26	.30	.30	100.00
Plympton, Devonshire.....	74.02	21.37	1.94	.40	.36	.82	.09	....	100.00
Newcastle-on-Tyne.....	64.63	29.78	3.23	.42	.41	1.09	.24	.20	100.00
Burton-on-Trent.....	58.08	36.89	2.26	.55	.14	.20	1.88	....	100.00
Wortley, near Leeds.....	65.25	29.71	3.07	.40	.61	.43	.12	.41	100.00
Poole, Dorsetshire	59.35	34.32	2.35	.43	.22	3.33	....	....	100.00
Hedgerley, Buckinghamshire.	84.65	8.85	4.25	1.90	.35	....	....	....	100.00
Kilmarnock, Ayrshire.....	58.92	35.65	2.49	.39	.35	1.14	1.06	....	100.00
Dinas, Glamorganshire.....	97.62	1.40	.49	.29	....	.10	.10	....	100.00

It should be observed, however, that the infusibility of any substance depends, not merely upon the chemical natures of its constituents, but also upon the manner in which those constituents are combined with one another. For example, granite, *per se*, is infusible at ordinary high temperatures, whilst pounded granite (or, in other words, a fine powder of quartz, felspar,, and mica, mixed in the same proportions) can be readily melted in the same degree of heat. The porosity in structure brought about by a coarseness of elementary particles would seem to add to the chemical infusibility of a material.

A most important physical peculiarity of clay—second only in importance to the property of plasticity—is its behavior on exposure to high temperatures.

It is well known that, as a general rule, all bodies are expanded by heat. Clay, however, appears to be an exception to this rule, being a mechanical mixture and not a homogeneous body; and it was observed by Mr. Wedgwood, that alumina, or clay in which alumina predominates, on being exposed to a red heat, begins to contract, and, as the heat increases, continues to contract regularly until it finally vitrifies, and so (by its permanent diminution in bulk) furnishes an approximate indication of the temperature to which it has been subjected.

Hence the Wedgwood pyrometer, which, by a comparison of the diminution in diameter of small cylinders of aluminous porcelain clay, placed between cylindrical brass rods forming a graduated gauge, supplies an empirical text of the degree of heat which those cylinders have sustained. It is proper, however, to remark that, as clay is a heterogeneous substance, and its contractions are not of necessity regular at different temperatures, this pyrometer—though useful for most practical purposes—fails to record the degrees of heat with precise accuracy; and there has yet to be devised a thermometer which will indicate with absolute exactness the very high degrees of furnace temperature.

Again the moulds of bricks are usually made larger than the intended products by abont $\frac{1}{10}$ or $\frac{1}{12}$ of each dimension, that being the ordinary proportion in which the dimensions of the brick shrink in burning. The cause of this strange property of clay is, I believe, still a matter of question.

By some it is supposed to result from an expulsion of the water of combination, and a consequent contraction of the primary pores, which produces an increased density of the mass. By others it is ascribed to an actual rearrangement of the constituent atoms by the influence of heat, which brings them into more intimate union. But, whatever be the cause, the property is important, and noteworthy in its bearing upon the present subject of investigation.

Fire-clays able to resist exposure to a high temperature without melting or becoming, in a sensible degree, soft and pasty, occur in various geological formations, and they abound in the coal measures in the carboniferous system. The following are a few of the best known localities in this country whence fire-clay is extracted: the valley in Derbyshire, between Burton-on-Trent and Ashby-de-

la-Zouch; the Southbridge district, in Worcester and Staffordshire (including Dudley, Tipton, Gornal, etc.); Newcastle-on-Tyne, in Northumberland; Wortley, near Leeds, in Yorkshire (including Elland, Storr's Bridge, Stannington, etc.; Wolverhampton, in Staffordshire; Poole, in Dorsetshire; Newport, in Monmouthshire; Kilmarnock, in Ayrshire; and Glenboig, at Coatbridge, near Glasgow, in Lanarkshire. To these should be added, as sources of our most celebrated fire-bricks, the aforesaid Dinas rocks, in the Vale of Neath, Glamorganshire; the *kaolinitic* refuse from porcelain clay at St. Anstell's, Cornwall, and Plympton, Devonshire; and a peculiar stratum of sandy loam, known as "Windsor loam," overlying the chalk at Hedgerley, a village about five miles north of Slough, Buckinghamshire, whose "red rubbers," were, in the times of our grandfathers, thought to possess surprisingly refractory powers.

In the following table is shown the percentage of the three most important constituents of these different kinds of fire-bricks, which have been practically tested in the Royal Arsenal furnaces, and analyzed by Mr. Abel, F. R. S., Chemist to the War Department. The maker's names are, for obvious reasons, omitted; but samples of most of these fire-bricks are to be seen in the School of Military Engineering at Chatham:

	Maker.	Silica.	Alumina.	Peroxide of Iron.	Alkalies, Waste, etc.
Stourbridge	A	65.65	26.59	5.71	2.05
Ditto	A	67.00	25.80	4.90	2.30
Ditto	A	66 47	26 26	6.63	.64
Ditto	B	58.48	35.78	3.02	2.72
Ditto	C	63 40	31.70	3.00	1.90
Newcastle	F	59.80	27 30	6.90	6.00
Ditto	G	63 50	27.60	6.40	2.50
Burton-on-Trent	L	56.63	35.31	2.99	5.17
Wortley	N	65 20	29.69	3.07	2.04
Poole	P	68 60	23 60	4.70	3 10
Plympton	Q	75.89	21 61	1.96	.54
Ditto	Q	76 70	20 10	1.70	1.50
Hedgerley	R	84 65	8.85	4.25	2 25
Holytown	S	59.48	31.45	6.90	2.17
Dinas	T	96.20	2.00	.28	1.70
Kilmarnock	V	59 10	35.76	2.50	2.64
Glenboig	X	62.50	34.00	2.70	.80

Experience with these samples justifies the general assertion that the refractory values of fire-bricks vary inversely with the amount of iron contained in them; and, as a general rule, the presence of 6 per cent. of peroxide of iron warrants the absolute rejection of a fire-brick. This component usually takes the form of little black specks or mottled particles which are embedded in the material, and can be plainly detected upon breaking the brick.

The essential qualities of a good fire-brick may, I think, be classified as follows: *Infusibility, regularity of shape, uniformity of composition, facility for cutting, strength* and *cheapness.*

The property of *infusibility* has already been touched upon in this paper; and it seems to forbid in the brick's composition so much as even 5 per cent. of peroxide of iron, or 3 per cent. of combined lime, soda, potassa, and magnesia. Generally speaking, a fire-brick should contain either silica or alumina in excess, according as it is intended for exposure to extreme heat, or for a possible contact with metallic oxides, which would exert a chemical reaction, decomposing it and acting as a flux. Thus, in theory, the arches of a furnace should be built of silicious bricks; its sides, bridge, and neck of aluminous bricks. Dr. Percy considers ("Metallurgy," p. 235) that, to boast properly of the quality of infusibility, a fire brick must well resist sudden and great extremes of heat; it must support considerable pressure at a high temperature without crumbling; it should not melt or soften in a sensible degree by exposure to intense heat long and uninterruptedly continued; and it

should withstand, as far as practicable, the corrosive action of slags rich in protoxide of iron. He recommends as a test, that the fire-clay should be formed into small sharp-edged prisms, which, on being enclosed in a covered crucible and subjected to an extreme temperature in an air or blast furnace, would denote a very high degree of refractoriness if the edges remained sharp, an incipient fusion of the material if the edges are rounded, and a thoroughly inferior quality of the fire-clay if the prisms were melted down.

M. Brongniart recommends the following process of test ("Traité des Arts Ceramiques," tom. 1, p. 342: "Si on veut juger la qualite refractaire d'une brique, c'est de faire un petit massif de six ou huit de ces briques sur deux rangs, et de l'exposer, un rang en evant dans un four a porcelaine a l'entree du feu dans le four. Le poids affaisera les inferieures si elles sont seulement ramollissables. Le rang anterieur ne doit pas entrer dans le judgement; il est toujours attaque, quelque refractaire qu'il soit; mais il sert a garantir le rang posterieur de l'action de la potasse des cendres a laquelle la terre la plus refractaire ne peut resister. C'est donc sur les alterations de ramollissement, de fusion, ou de boursouflement du rang postérieur qu'on peut juger la qualité refractaire d'une brique. Aucun moyen d'analyse ou d'essai en petit ne peut suppléer à ces véritables essais techniques." It may be remarked, however, that in this investigation, analysis, theory, and practice nearly always agree pretty closely.

In many works there is adopted the rough and ready, but very efficient mode of comparing the relative qualities of fire-bricks by placing them side by side upon the bridge of a reverberatory furnace, where they are subjected to the same heat and the same corrosive action of the fuel; and show very clearly, after a few days or weeks firing, which brick can best withstand these destructive influences under precisely similar conditions. I think this test is even superior to those suggested above. The corrosive action of suspended coal-dust in fluxing and gradually cutting away the exposed surfaces of brickwork, is extraordinarily great, even superior to the disintegrating influence of extreme heat.

Hence a great claim to economy of the Siemens Regenerative Gas Furnace; and Mr. Siemens affirms that the heat at which a suitably designed furnace can be worked is limited in practice only by the difficulty of finding a material sufficiently refractory of which it can be built.

Regularity of Shape requires that the brick's opposite sides should be truly parallel planes (excepting, of course, the special case where key hollows are left), and then arises sharp right-angled edges. The necessity for this requirement is obvious. In all forms of brickwork regularly moulded bricks produce even joints, prevent settlements, and effect economy as well as stability in the work. But in fire-brickwork, especially, an uniform shape of each individual component of the furnace permits, under extreme changes of temperature, an uniform expansion or contraction in all directions; it tends to preserve the relative proportions, and thus to insure the general stability of the entire mass of the brickwork.

Uniformity of Composition. The brick on fracture, should present a compact uniform structure—not necessarily close, for indeed some maintain that a coarse grit of texture is the chief requisite, and that a coarse uniform structure, though pleasing to the eye, is not favorable to the refractory powers of a fire-brick, since the particles should have a facility for contraction or expansion under heat, and the air cavities act as valuable non-conductors of heat. But the brick should be free from stones, cracks, and irregular air-hollows; and, on being struck, it should emit a clear ringing sound. The existence of this property usually involves that of the next.

Facility for cutting, i. e., a capability for being easily dressed with perfect accuracy, so that the brick shall not require a very violent blow, or split in a direction other than intended, or fall to pieces under a trowel. This property is an advantage in both building and repairs; but that it is not of paramount importance may be inferred from the fact that the best fire-bricks ever used in the Manufacturing District least fulfil this condition; yet no one, not even the bricklayers, whose tools suffer from the bricks' excessive hardness, would discontinue their use on this account. A fire-brick should never have its dressed surface, but only its "fire-skin" exposed to

the furnace flame, for reasons similar to those against the exposure of the rubbed surface of an ordinary building brick to the weather. Hence it is to employ as many forms of differently moulded brick as possible, and the accompanying diagrams show the dimensions of the special shapes found most convenient in actual practice.

Though it is impossible to propound an exact rule as to the percentage of the cost of labor and materials in furnace-work, their relative proportions may be roughly said to average 33 to 67 in new work, and 60 to 40 in repairs, such as cutting out bridges, clearing the necks, slag-holes, etc.

Strength is obviously necessary to enable the bricks to avoid breakage in transport, and to withstand the pressure and cross strains to which it will be subjected when built into the work. It is stated by Rankine ("Manual of Civil Engineering," p. 367), that the resistance to crushing by a direct thrust—the bricks being set on edge in a hydraulic press—is per sq. in., in weak red bricks, from 550 lbs. to 800 lbs.; in strong red bricks, 1,100 lbs.; in fire-bricks, 1,700 lbs. But experiments recently made in the Royal Arsenal upon isolated cubes of 1½ in. side, cut from fire-brick "soaps" and placed between small squares of sheet lead, gave the following results:

		Cracking weight, lbs. per sq. in.	Crushing weight, lbs. per sq. in.
Stourbridge	A	1,478	2,400
Ditto	D	1,156	2,245
Newcastle	G	889	1,512
Plympton	Q	1,689	2,666
Dinas	U	1,123	1,288
Kilmarnock	W	2,134	3,378
Glenboig	X	1,067	1,556

and the average crushing weight of ordinary stock bricks was found to be from 666 lbs. to 866 lbs. per sq. in. Hence, all fire-bricks known may be said to have a strength far in excess of that which would be ever required of them in actual work.

Cheapness may appear an impolitic, and, therefore, unworthy consideration, but it practically determines the selection of 9-10ths of the fire-bricks used in this country.

For example, the freightage to London per ton (from 320 to 370 9-inch bricks) costs, on an average, 5s. 6d. from Newcastle, and 13s. from Stourbridge. Hence the great advantage possessed, *cæteris paribus*, by the manufacturers of the former place over those of the latter. And supposing the cost in London of one class of fire-bricks to be one-half that of another, and the above statement to be true, viz., that in the cost of new work, labor : materials, :: 33 : 67 it will readily be understood that, from a momentary point of view, it might be perfectly immaterial to the furnace owner whether he used the cheap or the dear fire-bricks—always supposing that the former be not so bad as to disintegrate and drop into the metal, and that a comparatively frequent "standing" of some furnaces in his establishment were of no great consequence to his pocket.

But, in point of fact, the *pros* and *cons* of this question are seldom so nicely balanced as in the hypothetical case I have assumed, and the invariable experience of the manufacturing district is that the best fire-bricks prove always to be ultimately the cheapest.

I now propose to attempt some general descriptions of the usual processes in vogue for making certain of the best known classes of English fire-bricks. In this manufacture more than ordinary care is found requisite to insure an uniformly regular success from its processes, and it should be observed that there is almost as slight a similarity between the modes of manufacturing fire and building bricks as there is analogy between their uses. With the former, use involves incessant repair, and after a few months' wear in a busy furnace, entire renewal; with the latter, even if of worthless quality, a builder, careless of reputation and indifferent to the possible discredit of distant failures, can often construct without fear of immediate detection.

Yet, even with this practical check upon quality, all experience in fire-bricks induces a certain wise toleration, so that isolated or exceptional cases of failure should not be allowed to justify the sweeping condemnation of an entire class.

In the following remarks care will be taken, for obvious reasons, to avoid identifying those makers who have courteously allowed the writer to inspect their works.

Yet the official recommendations of a certain agent's fire-lumps taken in company with the experience of some of the most eminent iron and steel firms in

Sheffield, may be allowed to sanction the opinion that a very high degree of excellence should be attached to the fire-clay manufactories of the Burton-on-Trent district. With these manufactories, therefore it is proposed to begin.

Burton-on-Trent.

The clay is dug at a depth below the surface of about 20 ft. from open pits whose sides display the following strata :

	Thickness. ft.	in.
1. A common earthy or brick clay (burns white)	6	0
2. A kind of coal, locally termed "smut"	1	0
3. A kind of marl, locally termed "clunch"	6	0
4. A kind of coal, locally termed "smut"	0	6
5 Marl	6	0
6. Fire-clay :—a bluish-black or slate-colored clay, of which the upper stratum 10 in. or 12 in. thick (locally termed "top black") is best	6	0
7. A kind of coal, locally termed "smut"	1	0
8. Bottle-clay, for sewage and drain pipes	9	0
9. Iron-stone and "smut"	2	0
10. Pot clay, for yellow ware	succeeds.	

The fire-clay is worked up into bricks as fast as it is obtained from the pits. It is not here customary, as in many districts, to "weather" the clay by long exposure before use, but it is sometimes moistened with water in order to lay the dust.

It is usually transported from the pits, and through the works, in trucks upon a tramway of 1 in. rails and 18 in. gauge; but the wire-rope overhead transport system is being generally substituted, and this will permit the easy transport of about a 4 cwt. load in each of the "trunks" or boxes upon an endless steel wire rope suspended from poles, passing over Fowler's clip drum pulleys, and worked by small portable steam engines.

The clay is pulverized in Carr's Disintegrator, composed of four cylindrical cages, 6 ft. 3 in., 5 ft. 7 in., 4 ft. 9 in., and 4 ft. 7 in. in diameter, arranged concentrically on wrought iron disc plates, so that the steel bars or beaters are about 4 in. apart, and 1 ft. 4 in. wide.

These sets of beaters revolve in opposite directions, by means of an open and crossing driving band working their disc axles, so that the first and third cases rotate in a direction contrary to that of the second and fourth ; and they make about 200 revolutions a minute. The clay is lifted and delivered through a hopper into the interior of the machine (whose capacity is about 31 cubic ft.), by means of buckets upon a "Jacob's ladder" endless band, 10 in. wide. It is then driven through the mill, and ejected from it in a finely granulated state, by centrifugal force, at the rate of from 20 to 30 tons an hour. The clay is in this manner sufficiently pulverized to render a riddle unnecessary, if meant for fire-bricks ; but if for mortar or cement clay, it is passed through a wire mesh of 5 or 6 to the inch. The chief advantages of this machine over the ordinary "edge runner and pan" system of a mortar mill, consists in its ability to pulverize a moist, plastic clay as well as a dry clay, and in its power to disintegrate about 200 tons of clay per diem ; in which time the roller and edge runner process can, with the same steam power, grind only about 50 tons.

The bricks are fired in Hoffman and Licht's annular kilns, where, in successive chambers (each 15 ft. wide, 8 ft. 6 in. high, and holding about 20,000 bricks), different sets of bricks are dried, heated, burned, and cooled, by the currents of air feeding and escaping with the products of combustion from the same one fire. This form of kiln is found most economical in consequence of, *firstly*, the fuel being burnt with air already at an incandescent temperature ; and, *secondly*, the waste heat from both cooling and burning goods being entirely utilized in drying the new, fresh bricks about to be burnt, and raising them to a high temperature. The consumption of fuel in this form of kiln is, therefore, very small, in comparison with that in one of the ordinary form of construction ; and it is found that the burning of 1,000 bricks in the annular kiln requires only 2½ cwt. of Stavely dust coal, at 5s 6d. a ton, instead of 20 or 25 cwt. of large "Grosby slack" coal at 7s. a ton.

The difference of cost for coal alone, therefore, amounts to about 8s. per 1,000 bricks, and the saving of labor is also very considerable. The bricks so fired are peculiarly well formed, and well burnt ; the former, because they escape the additional handling and transport required by the dry-shed process ; the latter, because they are practically annealed by the gradual heating and gradual cooling in the successive processes of drying, heat-

ing, firing, and cooling, which extend over a period of about three weeks.

The Stourbridge fire clay district, including Amblecote, Brierly Hall, and the Lye, covers an area of from 8 to 9 square miles, with 6 fire-brick manufactories in Worcestershire, and 7 in Staffordshire.

From the pits on these works about 100,000 tons of fire-clay are annually raised, and the supply of fire-bricks has annually increased within the last 15 years from 14,000,000 to 30,000,000 per annum. In the neighborhood, the Quarry Bank Church is built entirely of Stourbridge fire-bricks; the Brockmoor Church is built partly of fire-bricks and partly of blue-bricks; and fire-bricks have been extensively used in the construction of the railway stations between Stourbridge and Birmingham.

The processes through which the clay passes during its manufacture into fire-bricks are 9 in number, viz.: digging, weathering, grinding, sifting, tempering, moulding, drying, and burning.

The Stourbridge fire-clay, or coal measure marl—a species of shale or slate-clay—is dug from pits (whose shafts are 6 ft. or 8 ft. in diameter, and steined) varying in depth from 120 ft. to 570 ft. It is generally found below 3 workable coal measures between marl or rock and an inferior clay. The former, overlying the fire-clay, is generally about 48 ft. thick. The fire-clay seam averages 3 ft. in thickness, never exceeding 5 ft., and thinning down to 5 or 6 in. when close to faults or small disturbances in the measures.

The middle stratum of the seam is always selected for the fire-clay, the top and bottom being thought too "strong." After being raised from the pits the fire-clay is picked over by women, who select the best lumps or "kernels" for glass-house pots, and reject for stains and mineral impurities. The pot clay is only found in small quantities—about sufficient for the glass manufactories—and costs on the spot 55s. per ton, whereas ordinary fire-clay costs on the spot only 10s. per ton; and 4 tons of clay (about 3½ cubic yards) are required to make 1,000 9-in. fire-bricks, whose local price is 50s.

Some of the glass-house pots recently made for one of the large plate-glass manufacturers at Ravenhead, weighed as much as 30 cwt. each when dry, and stood 6 ft. high.

The clay is exposed in spoil heaps over as large an area as can be secured, for from 3 to 18 months, according to the state of the weather. The action of frost, as with ordinary brick earth, is of great service in disintegrating the compact tough lumps of clay, and in dry weather the clay is frequently watered. In very wet weather a three months exposure will suffice for its proper "mellowing" or "ripening;" it ultimately slacks or falls to pieces. When new it is termed in the local phraseology "short and rough;" after due exposure it becomes "mild and tough." On some of the works the spoil heaps of clay contain over 10,000 tons, and it is estimated that 7 tons measure about 6 cubic yards.

After sufficient weathering, the clay is ground in a circular pan by 2 rollers or cylindrical stones, shod with iron rims 2½ in. thick, and weighing from 2½ to 3¼ tons a piece. They are driven by steam.

After being ground, the clay is carried on an endless band to a "riddle" of about 4 or 6 mesh to the inch for fire-bricks; 6 or 10 mesh to the inch for fine cement clay; 12 or 14 mesh to the inch for glass-house pot clay; the large-sized mesh being used for the sifting of the clay in wet weather. The large particles which will not pass through the "riddle" are carried back on an endless band to the pan and then re-ground.

As a general rule it is only for very large fire-brick lumps (such as blast furnace "tymps," 40 in. long, and 11 in. by 10 in.) that re-ground pots, crucibles, or bricks locally termed "grogg," are added to the clay before grinding; and fire cement clay is always ground pure.

After passing through the "riddle," the clay is tempered, or brought to a proper degree of plasticity by the addition of water.

It is then thoroughly stirred and kneaded in a circular cast-iron pug-mill by revolving knives projecting from a vertical shaft driven by steam power.

The clay is forced down by the obliquity of the rotating knives, and steams slowly from a hole near the bottom, whence, after being cut by wires into parallelopipedons, it travels on in an endless band to the moulding sheds.

The bricks are then moulded by hand in the usual manner, in moulds 10 in. by 5 in. by 3 in., or thereabouts, and dried

at a temperature of 60 or 70 deg. in sheds 120 ft. long and 30 ft. wide, beneath whose floors run longitudinally two flues, heated by small furnaces. In fine weather, however, the sun's heat is made to economize fuel.

The bricks are burnt in circular-domed kilns, or cupolas, locally termed "ovens," where they remain from 8 to 14 days, being fired with the real intensity of flame, or white heat, for about 4 days and 3 nights; they usually require 7 days to cool down. The fire is slowly increased, and gradually lowered; the time of burning is regulated by a kiln man in charge, who inspects the baking bricks from time to time through holes in the domed roof of the "oven." A chimney stack is on the outside of the kiln, and the flame burns with a down draught descending through holes in the floor, the fire-holes being merely openings left in the thickness of the wall of the kiln, and protected from the wind by buttresses long enough to allow room for the firemen to attend the fires. The coal is, of course, obtained from the pits which provide the clay. Most of the kilns hold each 12,000 bricks, but some are made large enough to contain each 30,000 or 35,000 bricks, the capacity of a kiln being roughly calculated upon the assumption that 10 bricks require 1 cubic ft. of space in the kiln.

For conveyance of the clay and bricks about the Stourbridge works, little trucks called "skips" are employed in the pits, and throughout the brick-fields. Their platforms, standing 1 ft. high, are 4 ft. square, and consist of 1½ in. planks. Their wheels, of cast iron, are 10 in. in diameter, with 2 in. axles. The rails, 2 ft. apart, consist of ¼ in. wrought-iron angle rails, 3 in. wide, and 1½ in. high.

The mode of fire-brick manufacture in the Newcastle district differs from that of Stourbridge in a very few and unimportant particulars.

The clay, in a spoil heap of 30,000 tons, is often exposed for 7 or 8 years, during which time it is picked over by boys, who remove pyritous fragments exposed on disintegration.

When required for fire-bricks, it is ground by cylindrical edge-stones, weighing 3 tons each, in a revolving pan, or else upon the ground, and then passed through a wire "riddle" of 6 or 8 mesh to the inch.

Throughout the works are 18 in. tramways, and pony trucks convey the materials from place to place. After tempering, moulding, pugging, and drying, the bricks are burnt in kilns about 15 ft. by 14 ft., by 10 ft. high, holding each 15,000 bricks.

They are fired for eight or nine days, during which time 5 tons of coals are consumed. The flame and hot air pass from a fire-box at one end of the kiln to outlet flues at the other end of it, and thence into an external chimney.

About 80,000,000 of fire-bricks are produced annually from the Newcastle district. *i. e.*, nearly three times the annual supply of the Stourbridge works.

Very excellent fire-bricks are made from the refuse of *Kaolin* or china clay, found in Cornwall and Devonshire.

Kaolin is produced by the disintegration of "pegmatite," or felspathic granite, under the action of the carbonic acid and moisture of the atmosphere; it then becomes basic silicate of alumina. The kaolinitic fire-bricks, containing very little iron or lime, possess extremely refractory powers, and have, in fact, been found in the Royal Arsenal air furnaces to be equal or superior in this respect to any other known fire-bricks in the kingdom.

With their rivals they compare as favorably for economy as for endurance; but the former is, of course, a specially local advantage, which might possibly disappear in another district.

Kaolinitic fire-bricks enjoy, however, a very high reputation in lead-smelting furnaces, converting vessels of the Bessemer steel process, the retort furnaces of gas works, kilns for burning iron pyrites, etc., etc. For the moderate heat to be withstood by ordinary boiler seatings, a burnt compound of kaolin, sand, and local clay, in equal parts, is found to be as good as the fire-lumps ordinarily employed.

The refractory powers of clay will, of course, by the addition of pure silicious sand, which can be produced by grinding sandstone if it is not obtainable in a state of nature.

The Dinas fire-brick is well worthy of attentive consideration, if, indeed, solely for the reason that it is, in the opinion of Mr. C. W. Siemens, F. R. S., the "only material of those practically available on a large scale, that I have found to resist

the intense heat at which steel-melting furnaces are worked." Now the average heat of a steel-melting furnace, measured by electrical resistance, may be accepted as 2,200 deg. Centigrade (=3,992 Fahrenheit), and that of the ordinary air-furnace, at welding heat, as the former, the Dinas brick, will last, it is found, for four or five weeks, though their thickness will, in that time, have been reduced from 9 to 2 in. But these extraordinary results, it should be remembered, have been only obtained in the Siemens Regenerative Gas Furnace, wherein, the flame being quite pure and free from the suspended dust which is usually borne from the fuel by the keen draught of air through an ordinary reverberatory furnace, the brickwork is not fluxed on its surface, and gradually cut away thereby, but it fails, if at all, from a general softening and fusion throughout the entire mass. For the ordinary puddling mill or air furnaces, the Dinas bricks, notwithstanding their ability to resist very high temperatures, are somewhat troublesome in actual practice. They are very friable, porous (and thus imbibe moisture freely), they swell extremely with heat, and do not contract to their original dimensions.

If allowed to cool down (and it is customary to let the furnaces "stand," in most works, from mid-day on Saturday till mid-day on Monday) they are apt to crack, flake in fragments, and then fly to pieces in consequence of the decrepitation of portions of the quartz composing them. From their extreme tenderness they are unlikely to prove durable if applied in portions of furnaces where they would be subjected to much mechanical wear.

Yet their refractory powers are remarkably great, and they bear a very high reputation with many owners of copper-smelting, iron, glass, gas-works, coke ovens, etc., and they seem to be highly esteemed for the arches of reverberatory furnaces in the copper works of Swansea, at Middlesborough, and at Ebbw Vale.

The tabulated analyses show the high percentage of silica which these bricks contain; and from their silicious nature it is obvious that they should not be exposed to the action of slags rich in metallic oxides, or to the fumes from lead ores, or to proximity with alkaline substances generally.

IRON ELECTROTYPE.

From "Engineering."

The art of electrotyping, which owes its discovery almost to accident in the year 1839, has since that time grown into a very extensive branch of manufacture. The discovery of this most useful art was made almost simultaneously in England and in Russia. In England Mr. Thomas Spencer and in Russia Professor Jacobi have to be individually credited with the invention, which has since been developed and brought to the degree of perfection in which we now find it in daily practice. So far the reproduction of engraved plates, medallions, and objects of art has only been effected in the softer metals, such as gold, silver, and copper, although attempts were long since made to reproduce them in iron. Few persons probably were aware, however, that this important object had been accomplished, until, like ourselves, they saw a case containing some beautiful specimens of iron electrotype in one of the corridors of the late International Exhibition at South Kensington. The specimens were placed there about 3 months before the close of the Exhibition, and were exhibited by Messrs. Bryan, Donkin and Co., of Bermondsey, as agents for the inventor. These specimens consisted of bank-note and various other plates, medals, medallions, and a page of printing type electrotyped in iron. This new process has been perfected by M. Eugène Klein, who is at the head of the chemical department of the Imperial State paper manufactory in St. Petersburg. Many difficulties have arisen and have been successfully surmounted in developing this process to its practical issue. Attempts were made to effect the object so far back as the year 1846, but which were unsuccessful, and it was about 20 years before the problem was definitely solved. The importance and reality of the progress, however, are now unquestionable, and an extended knowledge of

the process must inevitably lead to its general adoption. At the present time we believe its application is confined to the Russian Imperial State paper works, where it has been in active operation for the past three years, the iron plates replacing those of copper for bank-note printing and for other similar purposes. The application of the invention, however, extends to all the other branches of the art of electrotyping as demonstrated by the specimens to which we have already referred.

From a paper upon the present subject, read by Professor Jacobi before the Academy of Sciences in Russia, in 1868, it appears that in the previous year M. Feuquières sent to the Paris Exhibition some specimens of iron electrotype which presented a fair appearance as regarded surface, but still were inferior to those produced by M. Klein in the year following. M. Feuquières does not appear to have published the process by which he obtained his results, and he, moreover, only spoke of it with the greatest reserve. Professor Jacobi, however, states on the authority of Professor Varrentrapp, of Brunswick, that the process and the bath employed differ essentially from those of M. Klein, whose results may be considered as being perfectly independent.

Referring to the process of electrotyping in iron, Professor Jacobi observes that the good quality of the iron deposit depends principally upon the greater solubility of the anode. The augmentation of its surface not having produced the desired effect, M. Klein conceived the idea of combining the anode of iron with another of copper. The Professor varied this combination by replacing the copper with horn charcoal, which gave more powerful results. The effects of this combination were thus rendered complete, the metal negative combined with the iron in the same bath formed a duplicate layer, which worked as a cathode opposite the iron, and as an anode by its combination with the copper wire, or the positive pole of the pile, which furnished the principal current. The surface of this electrode consequently disengaged hydrogen and oxygen simultaneously, which combined in proportions which form water. The surplus hydrogen freely disengaged itself, or produced a polarization of the electrotype. If, observes the Professor, the oxygen is most abundant, and if the electrotype consisted of an inoxidable substance, such as horn charcoal, it would also have disengaged gas, and have given a feeble polarization. If, however, the electrotype is oxidable like copper, it will be oxidized and dissolved. By immersing a galvanometer in the circuit, Profes or Jacobi has observed the deviation of the needle diminish by degrees, whilst the current was very feeble, and it became perfectly still after the force of the current had been increased to a certain degree. At length, passing that degree, the Professor noted that the deviation again became inconstant. By means of the galvonometer, it therefore becomes easy to so regulate the current as to disengage neither the oxygen nor the hydrogen from the cathode.

So far, Professor Jacobi. Turning now to a letter from M. Klein, which was placed before the Russian Academy of Sciences in 1868, we have recorded the methods employed by him in the production of iron electrotype. M. Klein saw M. Feuquières' specimens at the Paris Exhibition, and, encouraged by Professor Jacobi, he, on his return to St. Petersburg in October, 1867, renewed his attempts to electrotype in iron. The scientific interest which attached to the new development, and the eminently useful applications of which he saw it was susceptible, especially in the departments of engraving and printing, stimulated M. Klein, and in the early part of 1868, he had accomplished his object. The medals produced in the early part of M. Klein's researches, showed on their reverse, porosities and deep hollows which penetrated nearly through the thickness of the deposit. These cavities were also observable in great numbers in the productions of M. Feuquières. In M. Klein's later specimens these singular cavities—which probably proceeded from bubbles of gas—entirely disappeared, and their reverses are in no way inferior to those of copper specimens produced under the best conditions. The starting point of M. Klein was the steeling of engraved copper-plates, which process was effected in a bath composed of the chlorates of ammonia and iron, to which he added a small proportion of glycerine. Those, however, who have paid attention to this steeling process have had occasion to remark that in giving the deposit of iron a greater thick-

ness, the surface cracked, and the deposit detached itself from the cathode in excessively brittle flakes. It became necessary, therefore, to employ baths of two different classes, composed of sulphate of iron and sulphate or chlorate of ammonia. Finally, M. Klein devised three baths after the formulæ Fe O, $S O_3 + N H_4 O$, $S O_3 + 6 H O$.

The first bath consists of a concentrated solution of crystals of double salt Fe O, $S O_3 + N H_4 O$, $S O_3 + 6 H O$ above mentioned. The second bath was composed by mixing the concentrated solution of each of these two salts in the proportions of their equivalents. At length M. Klein obtained the third bath by taking a solution of sulphate of iron, precipitating the iron by carbonate of ammonia and dissolving the precipitate by sulphuric acid, getting rid of all excess of acid. In preparing the baths of the second class, M. Klein, as we have stated, mixed the solutions of chlorate of ammonia and sulphate of iron in the proportions of their equivalents. Another method employed is, to dissolve in a solution of sulphate of iron as much chlorate of ammonia as it will readily absorb at a temperature of about 66 deg. Fahr. All these baths were concentrated as highly as they could be. As an anode, M. Klein employed iron plates giving a surface of about eight times that of the copper cathode. In using a Daniell battery for the decomposition the deposit was formed in 24 hours upon the whole of the cathode. The deposit, however, was full of flaws, and was easily detached and broken up into fragments.

As it often happens that the solution of sulphate of copper improves by use, M. Klein hoped that the iron solutions would act in a similar manner. He therefore continued the experiments for several days without, however, obtaining any better results. Under the advice of Professor Jacobi, instead of a pair of Daniell cells for each of the five stages of decomposition, he then employed four pairs of feebler Meidinger cells, uniting them in series with the five stages of decomposition. This arrangement was found to give a smaller development of hydrogen at the cathodes and better final results. The deposits, however, were not yet perfect, some exhibiting porosity and others being furrowed.

Conceiving from previous experience that this was due to acidification of the bath, M. Klein tested it, and found a very decided acid reaction. He attributed this acidification to the circumstance that the quantity of iron deposited on the cathode was greater than that dissolved by the anode. It was therefore necessary to give the anode a greater degree of solubility, and as that could only be effected by increasing its area, M. Klein conceived the idea of placing in the bath a plate of copper and uniting it with the iron. The result of this combination was very remarkable; not only were the baths of the first class rendered neutral after several hours, but the deposits became much more uniform. Their color was a dull grey; they adhered perfectly to the cathode without warping or cracking in any part. During the first 24 hours the surfaces remained perfectly even, but afterwards they began to exhibit minute cavities similar to the appearances often produced upon galvanic deposits of copper. These cavities, however, rarely penetrated to the depth of the deposit. Their production is attributed to the superabundant disengagement of gas on the surface of the cathode. It probably happens that these bubbles attach themselves strongly enough to hinder the formation of the deposit. If the energy of the current becomes too great, these annoying phenomena are produced more frequently. By reducing this energy in the process, and having only an imperceptible disengagement of gas by diminishing the concentration of the bath, or augmenting the resistance of the solid portions of the circuit, the formation of these cavities entirely disappeared, and the beautiful results to which we have already referred have been obtained. A microscopical examination of the reverses of the deposits produced by M. Klein's final process fails to discover any porosity or irregularity in the specimens.

On leaving the bath the iron is as hard as tempered steel and very brittle. Reheated to a dull red heat it loses much of its sharpness and hardness. Heated to a cherry red it becomes malleable, and may be engraved as easily as soft steel. If the deposits are produced in good condition, and annealed uniformly and with the necessary precautions, they are neither subject to warp nor bend. There is

no contraction, but on the contrary, a slight degree of expansion, almost imperceptible, however. Owing to the necessity of having bank-note and similar plates identical in every respect, it is of the first importance that they should not be distorted nor have their dimensions altered in the process of annealing. It appears that the galvanic deposit of iron has not only permanent magnetism, but that, like soft iron, it receives the magnetism of position.

We have now received both the failures and the successes of M. Klein. Of the importance of the practical application of the process, there can be no doubt whatever. By replacing plates of copper by those of iron, greater facilities will be afforded for producing publications, works of art, and especially bank-notes and checks. Iron electrotype plates are found to be almost indestructible. They not only can be printed from an almost unlimited number of times, but they are better calculated than those of copper to withstand those inevitable accidents constantly occurring in printing establishments. Printers are sometimes obliged to set aside as useless their best plates, which are often damaged by a grain of sand, or by a chance knot in the paper. These accidents not only involve the expense of renewing the plates, but sometimes occasion interruptions and delays in works of a very pressing nature. These are some amongst the many which may be expected to accrue from the introduction of iron electrotype.

IRRIGATION v. DISINFECTANTS.

From "The Engineer."

Ever since the commencement of the sewage difficulty, the rival claims of the irrigation and disinfectant partisans have been prominently placed before the public; yet the problem is still unsolved. The results of irrigation are tangible and appreciable; so also, it is said, are those of the deodorizing and disinfecting systems. Our own opinion on the respective advantages of the two are too well known to require any recapitulation on our part. The whole subject is now on its trial, and until the experiment which is being conducted with regard to the sewage of the metropolis is a success or a failure, all criticism may be fairly suspended. The task which the Native Guano Company have undertaken to accomplish at Crossness differs in no respect from that which has always constituted hitherto the insuperable obstacle to a satisfactory solution of the important question. It is not intrinsically of an arduous character. It involves only two conditions. The one is the purification of the effluent water; the other the utilization of the solid residue. Both of these must, however, have a reference to some standard. The former ought to attain to that prescribed by the Commissioners appointed to inquire into the pollution of rivers. Perhaps this is of a rather stringent character. One thing is nearly certain, viz., if the Conservators of the Thames elect to adhere to this standard, there will be an end to the experiment to which we have alluded. There is no difficulty in purifying the metropolitan sewage to an extent which will allow the effluent water to pass into the river in a state of almost absolute purity compared to the filth which is at present pumped into it. It remains to be seen if the Board of Conservancy will be content with an amelioration instead of a cure of the evil. That the result of the forthcoming experiment will very materially improve the present condition of the sewage discharged into the Thames, we have not the slightest doubt. That it will not purify the effluent water so as to bring it up to the standard of the Rivers' Pollution Commissioners, we have also not the slightest doubt. But between this standard and that which will probably satisfy the Conservators there is, fortunately for the experimentalists, a wide margin. So far as the pollution of the Thames is concerned by metropolitan sewage, the term applied to its guardians is a complete misnomer. They are able to hold their own with the small fry, but when they have to tackle a big fish, such as the Metropolitan Board of Works, they are nowhere. They give no mercy to the riparian small towns and villages situated beyond the municipal boundary, and yet allow the whole sewage of the metropolis to be discharged into the river they are presumed to conserve.

It may be assumed that with respect to the Thames the first condition of the sewage question may be considered to be partially fulfilled. In other words, the effluent water which will be subsequently discharged into the river from the new works in course of erection at Crossness, will be comparatively so pure with respect to that which has hitherto been pumped into the stream, that it will be considered to leave nothing to be desired. The proof of its actual purity will be the analysis of it, which there is no doubt will be undertaken by competent authorities. There now remains the second part of the question to be taken into consideration. It involves the manufacture of the salable manure, and collaterally the cost of its production. It is this part of the plan that is to pay for the whole operation, and recoup the shareholders for the money they have expended. There are a great variety of opinions respecting the manure made from the solid residue of the purified effluent sewage water. It is asserted that it commands a high price in the market, and is eagerly sought for by agriculturists, while some maintain that it will barely pay the expenses of cartage. It should be borne in mind that the mere fact of a manure rich in manurial ingredients being manufactured from sewage residue, is no test of the financial success of the process by which it is produced. Nothing is easier than to make a rich and valuable solid manure. All that is required is to put the necessary ingredients in, and the thing is done. Nothing more is necessary than to combine the manurial elements with the actual sewage residue, and then say there is a valuable solid manure manufactured from sewage. But really to effect the object in view in such a manner as will pay the cost of manufacture is to prepare the manure from the sewage, and from the sewage alone. It is here that the uncertainty prevails. What proportion of the manurial value of the solid material is due to the sewage, and what to the ingredients purposely combined with it, the value of which latter is previously well known? Chemists and analysts can ascertain the composition of a manure, and from that assign its theoretical agricultural value. But the farmer is the person who really determines the practical, that is, the profitable value of the manure, and on this point chemists and farmers differ very widely. If the material prepared in the manner described derives its value, not from the sewage, but from certain ingredients mixed with it, the utility of which is recognized by all, the farmer may as well purchase those ingredients in some other shape. There is obviously no gain in buying a lot of dirt to act merely as the vehicle for a comparatively small quantity of genuine manure.

We, as well as everyone else, are waiting with much interest the result of the trial at Crossness, for there is not the slightest doubt that, omitting all consideration of the irrigation system of utilization of sewage, the general question very much depends upon the success or failure of the operations which are to be carried out there. With the exception of the A. B. C. scheme, all the others of a similar nature, having the same end in view, have, from one cause or another, gradually fallen through. That one alone, notwithstanding the vigorous and perhaps rather severe condemnation passed on it by the Rivers' Pollution Commissioners, has kept its head above water, and attempted a solution of the great problem on a scale of magnitude commensurate with its importance. Indeed, to judge from the market price of the shares of the Company, it ought to be the most profitable investment open to capitalists. Our own views on the subject of the utilization of sewage have been so often expressed that we need not recapitulate them. While still adhering to those opinions, and believing that the irrigation principle is the best, we should nevertheless be rejoiced to witness the success of the experiment at Crossness. But the trial must be complete in every sense. It will not be sufficient to establish that a portion of the metropolitan sewage can be treated successfully for a brief period. It must be demonstrated that the method is capable of dealing with any quantity for any length of time continuously. Were the system once in active operation, a breakdown would be an event of the gravest moment. The flow of sewage is incessant day and night, and the means for providing for its treatment must be also always available. This is a difficulty not to be despised, even when it is confined to small towns, but it becomes very formidable when it assumes the proportions resulting from its connection with a city of the size and population of the metropolis.

STRAINS IN STRAIGHT GIRDERS AND TRUSSES.

By E. SHERMAN GOULD, C. E.

I.—STRAIGHT BEAMS AND GIRDERS.

A. *Horizontal Strains.*

Let us consider the effect of a weight placed upon the centre of a beam, resting on two supports.

It is evident that each support sustains one-half of the weight. The principle of reaction permits us to consider the beam as being pressed upward at each end with a force equal to the pressure on the supports, against the weight at the centre, considered as a common fulcrum.

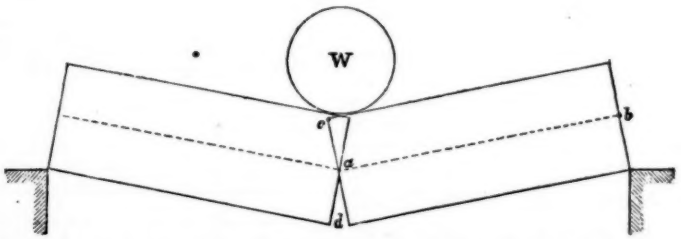
This force acts with a leverage equal to half the length of the beam, and tends to crush the beam together at the top and tear it asunder at the bottom. Calling the weight at the centre W, and the length of the beam L, the strain tending to fracture the beam may be written

$$\frac{W}{2} \times \frac{L}{2} = \frac{W\,L}{4}*$$

This is the strain tending to produce rupture at the centre. It is constant for a given weight and length of beam, irrespective of the shape or material of the beam. It is resisted at the centre by the strength of the material of the beam, multiplied by its depth at the centre.

This must be further elucidated. We have seen that the weight tends to compress the top of the beam and extend the bottom. It is clear that there must be some point in the strained section where the character of the stress changes, that is, where it ceases to be compressive and becomes tensile, and *vice versa*. This point is assumed, in a straight beam, to be at the centre of its depth. Around this point, under the influence of the weight, the beam tends to turn with a force equal to $\frac{W\,L}{4}$. Thus

FIG. 1.



To this crushing and extending force the material of the beam opposes a certain resistance, which is the more effective as the depth of the beam, and therefore the leverage with which it acts, is greater. In effect, the system of strains and resistances, as shown above, constitutes two bent levers. The force $\frac{W}{2}$ acting with the leverage $a\,b$, tends to turn the beam around the point a, while the resistance of the material of the beam to compression and extension, acting with the respective equal leverages $a\,d$ and $a\,c$ tend to keep it in a straight line. It was early seen in the study of the resistance of materials, that the material in the top and bottom edges of a beam was rendered the most effective from the greater leverage with which it acted, and the effort to concentrate most of the material at those points, led to the introduction of girders formed with top and bottom flanges, joined by a web. As certain materials resist one kind of strain better than they do the other, the scantling of the flanges is proportioned with a view to establishing an equality of resistance at top and bottom.

Thus we have a force $\frac{W\,L}{4}$ tending to turn half the beam, around the point a, resisted by a certain factor R (the resistance of the material to compression) mul-

* It is of course unnecessary to explain that it is only the moment of the reaction of one support which tends to produce rupture. Should the student have any difficulty in realizing this, he need only recall the effect produced by two men of equal strength pulling against each other, on a rope. Though both pull, there is no more strain on the rope than if one end were made fast and only one man were pulling upon it.

tiplied by *a c*, *plus* a factor R' (the resistance of the material to extension) multiplied by *a d*. But the girder is, as we have seen, so constructed that R=R', the resistance of the girder is therefore R ($a\,c + a\,d$). But $a\,c + a\,d$=D, or the depth of the girder at the centre. We have then, for the resistance of the girder at the centre,

R D.

In order that the girder may sustain the weight, it is necessary that this force be at least equal to that tending to produce rupture. That is, we must have

$$R\,D = \frac{W\,L}{4}.$$

From which we obtain

$$R = \frac{W\,L}{4\,D}$$

Example.—What is the value of R for a wrought-iron girder, 1 ft. deep from centre to centre of flanges, resting on two supports 12 ft. apart, and bearing a weight of 12 tons, placed at the centre?

Here

$$R = \frac{12 \times 12}{4 \times 1} = 36 \text{ tons.}$$

Taking the safe resisting strength of wrought iron to crushing and tearing* at 5 tons per sq. in., the flanges of the above girder must have a section of 7.2 sq. in.

The above formula gives the strain at the centre of the girder. To obtain the strain at any other point, we must substitute the distance from that point to the nearest abutment, for $\frac{L}{2}$ in the formula. That is the strain at any point in the flanges of a girder supported at both ends and loaded in the middle, is equal to the reaction of the supports multiplied by the distance of the given point to the nearest support. If in the above example we wished to find the value of R for a point half way between the centre and one of the supports, we should put

$$R = \frac{12 \times 3}{2} = 18 \text{ tons.}$$

If the load be applied at a point other than the centre, the weight borne by either support is to the whole weight as the distance from its point of application to the other support is to the whole length of the girder. Thus, in our example, if W be placed half way between the centre and the right support, the weight sustained by that support is $\frac{3}{4}$ W = 9 tons, and the weight sustained by the left support is $\frac{1}{4}$ W = 3 tons, the sum of the two making up the whole load. The moments of the reactions of the supports around the point of application of the load are equal. Thus in the above, $\frac{3}{4}$ W $\times$ $\frac{1}{4}$ L = $\frac{1}{4}$ W $\times$ $\frac{3}{4}$ L. The strain at this point is therefore given by either side of the above equation.

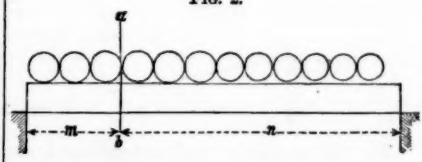
The strain at any other point is equal to the moment of the reaction of the support between which and the applied weight the given point is located, around such point. This is an extension of the rule enunciated in reference to a central weight. If, in our example, W be placed 3 ft. from the right support, the value of R for a point 3 ft. from the left support is

$$\frac{W}{4} \times \frac{L}{4} = 9 \text{ tons.}$$

It will be seen in all cases of a single weight, that the maximum strain occurs at the point of application of the weight.

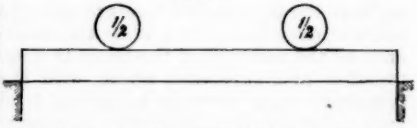
Let us now consider the case of a girder supported as before, but over which the weight is evenly distributed.

FIG. 2.



As far as the pressure on the supports and the strain on the flanges at the centre are concerned, we might consider the weights as being concentrated in equal groups about the centres of gravity of the two halves of the girders, thus :

FIG. 3.



Each support bears half the weight, that is the right support bears $\frac{3}{4}$ of the right half weight and $\frac{1}{4}$ of the left half weight, making $\frac{W}{2}$ in all, and the same

* Though the resistance of wrought iron to a tensile strain is considerably greater than its resistance to compression, it is found in practice, particularly with riveted flanges, that it is not safe to use a smaller section at the bottom than at the top.

reasoning applies to the left support. The strain at the centre is obtained by calculating the separate action at that point of each half weight, and taking their sum. Thus, the reaction of the right support from the left half weight being $\frac{1}{4}$ of $\frac{W}{2}$, the strain which that half weight exerted at the centre is $\frac{W}{8} \times \frac{L}{2} = \frac{W\,L}{16}$. The other half weight exercises an equal strain at the same point, and the sum of these gives a total strain of $\frac{W\,L}{8}$. We have therefore, in the case of a girder so loaded, $R = \frac{W\,L}{8\,D}$ for the central strain, which is half that produced by an equal weight concentrated at the centre.

By taking the strain at other points between the two weights, we find it equal throughout the central segment.* This fact precludes the using of this transformation of the weights in determining the strain at various points in a girder uniformly loaded. It is always possible, however, to ascertain the strain at any given point in a girder so loaded, by supposing the weights grouped at the centres of gravity of the segments into which such point divides the girder. Thus, to determine the strain at a point distant m from the left support (Fig. 2), we might consider the weights on each side of $a\,b$ as concentrated at the centres of gravity of their respective segments, viz.: the weights on m concentrated at $\frac{m}{2}$ and those on n at $\frac{n}{2}$. Reasoning as for the strain at the centre, we should find the strain at $a\,b$ due to the weights on

$$m = \frac{m\,W}{L} \times \frac{m}{2\,L} \times n = \frac{W\,m^2\,n}{2\,L^2},$$

and that due to the weights on

$$n = \frac{W\,n^2\,m}{2\,L^2}.$$

Adding, we have,

$$\frac{W}{2\,L^2}\,(m^2\,n + n^2\,m)$$

for the actual strain at $a\,b$.

But this method of reasoning leads, as we see, to a rather complicated formula. It is better to treat the question in the following manner: We have, as in the case of the girder loaded at the centre, the reaction $\frac{W}{2}$ of the right support acting upward with the leverage n. In the present case however, we have a certain amount of resistance to this strain, due to the distributed load upon n, and independent of the resistance of the girder itself. That is to say, the loaded segment n acts against the upward force $\frac{W.n}{2}$ to the extent of the moment of the weight upon its centre of gravity around the given point. The weight on n is $\frac{n}{L}$ ths of W. The strain and resistance at $a\,b$ are therefore expressed by the equation

$$R\,D = \frac{W\,n}{2} - \frac{W\,n}{L} \times \frac{n}{2},$$

whence

$$R = \frac{W}{2\,D}\,\frac{(n - n^2)}{L} = \frac{W}{2\,D\,L}(L\,x - x^2)$$

In the last expression x has been substituted for n, as either of the segments m and n gives the same result.

If the above equation be resolved for the value of D, and R be made constant, the successive values, D, will vary as the ordinates of a parabola.

The previous problems, where the strain at any point is ascertained by the reaction of that support between which and the weight the given point is located, may also be resolved, though not so readily, by taking the moment of the reaction of the other support, less the moment of the loaded segment, as in the present case.

The maximum strain, when a girder is uniformly loaded, is at the centre. When the girder is loaded with a single concentrated weight, the maximum strain is at the point of application of such weight. If now a girder be at the same time subjected to an equally distributed load, and a single weight placed at some point other than the centre, the position of the point of greatest strain as determined by either one of these loads considered separately, will evidently be modified by the action of the other. The maximum strain in the flanges of a girder, however loaded, occurs at the point which forms the centre of equal moments of the reactions of the two supports. Therefore, to obtain the point of greatest strain in a

* We may therefore obtain the strain throughout that portion of a girder comprised between two equal and symmetrically placed weights, by taking the moment of the reaction of one of the supports around the point of application of the weight nearest to it.

girder bearing two loads, one uniformly distributed and the other concentrated at a single point, we must find the total reaction of each support from both weights, and then determine that point in the girder around which the moments of the same shall be equal.

Suppose, for example, a beam loaded with the equally distributed load W, and also with a single weight equal to W placed midway between the centre and the left support. The reaction of the left support is $\frac{W}{2}$ from the distributed, and $\frac{3}{4}$ W from the undistributed load. Total reaction of left support $\frac{5}{4}$ W. The total reaction of the right support is found to be $\frac{3}{4}$ W. Let L represent the length of the beam and x the distance of the centre of equal moments from the left support. Then $\frac{5}{4}$ W $x = \frac{3}{4}$ W (L − x), whence $x = \frac{3}{8}$ L.

B. *Vertical Strains.*

So far we have considered only the strains in the upper and lower edges or flanges of a beam or girder, and in the case of a solid beam, these horizontal strains, as they are called, are the only ones of which it is necessary to take account. But when a girder is formed of flanges joined by a comparatively light web, it becomes necessary to ascertain the vertical or shearing strain, that is, the strain which the web must sustain in keeping the two flanges apart, in order to proportion the scantling of its parts to the duty it may be called upon to perform.

These strains are entirely independent of leverage. In the case of a single weight applied to the top of a girder, the tendency is to crush the web with a force equal to the reaction of the supports. Thus, if the weight be applied at the centre, the shearing strain throughout the whole girder is $\frac{W}{2}$. If it be applied midway between the centre and one of the supports, the shear on all parts of the web between it and that support is $\frac{3}{4}$ W, and on all parts between it and the other support, $\frac{1}{4}$ W.

When the girder is uniformly loaded, the case is different. If we consider a girder loaded with 12 equal weights (Fig. 2), it is obvious that the web at the ends of the girder must be strong enough to sustain the whole 12 weights—6 on each end. At the points between the 1st and 2d, and the 11th and 12th weights, it need be only strong enough to sustain the 10 intermediate weights, and so on to the centre, where the shearing strain is *nil.* Therefore, in a girder uniformly loaded, the shearing strain at any point is equal to the weight on that part of the girder comprised between the centre and the given point, and this strain is the same at the corresponding point on the other side of the centre. We see by this that the point of maximum horizontal strain corresponds to that of minimum vertical strain, and *vice versa.*

There is a curious phenomenon connected with the shearing strain of an equally, as compared with that of a partially loaded girder. One would suppose that the greatest strain of this nature at any section, $a\ b$ (Fig. 2), would occur when the whole girder was loaded throughout. But such is not the case. If the 3 weights to the left of $a\ b$ be removed, the shear at $a\ b$ will be augmented. To investigate this phenomenon, let L represent the whole length of the girder; w the weight per unit of length (that is the weight per foot, yard, or whatever unit is used in L); n the segment of L bearing the load; m the unloaded segment. Referring to Fig. 2, to get the shearing strain at $a\ b$ when the 3 weights on m are removed, we may suppose those on n concentrated at its centre of gravity, and calculate the weight sent by them in this position to the left support, which will be the shearing strain at $a\ b$ and throughout the unloaded segment.

The centre of gravity of n is $\frac{n}{2}$, and the weight on n is n W. Accordingly, the weight carried by the left support, would be the half of $\frac{n}{L}$ ths of n W, or $\frac{n^2\ W}{2\ L}$, which would be the shearing strain sought for. If now we replace the 3 weights on m, so that the girder becomes entirely covered. We find the shearing strain at $a\ b$ to be

$$W\frac{(m+n-m)}{2} \text{ or } W\frac{(n-m)}{2}.$$

Subtracting this from the strain at the same point when the girder is partially loaded, we have

$$\frac{n^2\ W}{2\ L} - W\frac{(n-m)}{2} = \frac{W}{2\ L}(n^2 - L\ n + L\ m).$$

But $n^2 - L\,n + L\,m = m^2$, so the excess of strain at any point of a girder when only the longer of the two segments into which it divides the girder is loaded, over the strain at the same point when both segments are loaded $= \frac{W\,m^2}{2\,L}$.

It seems a little difficult to realize that a strain is actually augmented by a reduction of weight, and if experiment were not at hand to verify theory in this matter, one could hardly accept the fact.

For a further discussion of this point, see Stoney on Strains, Vol I., p. 30.

II.—STRAINS IN STRAIGHT TRUSSES.

We have now considered the strains produced in a beam or girder supported at both ends, under all the circumstances of loading which can ordinarily occur. We will proceed to investigate the effect of these strains in bridge construction.

A bridge truss may be considered as a large girder, and when the web is formed of plates or riveted latticing, the strain at any given point is ascertained by the direct use of the formulas already given. When, however, the web is formed by trussing, the varied disposition of the different members constituting the truss, renders the calculation more complicated; for in determining the strain upon any member of the web or truss, it is necessary to ascertain precisely what amount of the weight is sustained by that member, and in finding this strain for any given point, it is often necessary to take some other point, more or less distant from the one actually in question, as that which determines the loaded segments.

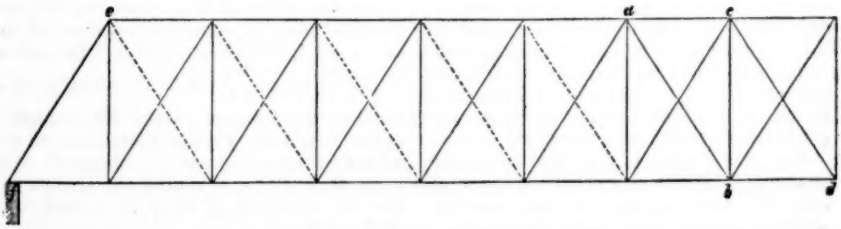
The first effort to most effectively dispose of a given amount of iron in the construction of beams, led, as we have seen to the introduction of the flanged plate girder, of which the tubular system is only a special adaptation. It was soon found, however, that this system, as applied to bridge construction, failed to permit of a proper depth between the flanges, as the thin plates composing the web, yielded by buckling, when their depth was considerable. To obviate this, the lattice girder was introduced, which may be regarded as a plate girder, the web of which has been folded into narrow strips, and these placed diagonally between the flanges. The result of this arrangement is, that while only the same amount of material is used, it is so disposed as to yield less readily to lateral flexure. Still further efforts to increase the concentration of web material, led, with other considerations, to the various kinds of triangular trussing now in use.

The strains on bridges are due to two causes:—the weight of the bridge itself, which acts as a uniformly distributed load, and the weight of the train, which, in its passage over the bridge, develops all the strains we have already investigated.

One of the simplest forms of bridge truss, is that known as the Howe. This truss is composed of top and bottom chords, vertical ties, and inclined braces and counterbraces.

We will suppose a truss constructed on this principle, 200 ft. long, 18.75 ft. effective depth, with the vertical ties 12.50 ft. apart. The truss is thus divided into 16 panels. The roadway rests on the bottom chord. One half of such a truss is shown in the figure.

FIG. 4



We will assume the weight of the bridge itself to be 160 tons of 2,000 lbs., and the weight of a train of locomotives completely covering the bridge to be 320 tons. As we will conduct our reasoning upon a single truss, we must take half of these weights only in our calculations. The length of a panel will be taken as the

unit of length. We have therefore the following symbols and values:

L = length of truss = 16.
D = depth of truss = 1.5.
W = weight of loaded truss = 240 tons of 2000 lbs.
w = panel weight of truss = 5 tons of 2000 lbs.
w' = panel weight of load = 10 tons of 2000 lbs.
$w'' = (W + W')$ = 15 tons of 2000 lbs.

We will first calculate the horizontal strain in the lower chord, at the end of each panel, beginning at the one nearest the abutment. This strain is maximum when the bridge is covered with its load, and is constant throughout each panel length of the chord. We make use of the formula

$$R = \frac{W}{2\,D\,L}(L\,x - x^2),$$

which we resolve for the successive values of x from 1 to 8. The constant $\frac{W}{2\,D\,L} = 5$, and we obtain from the formula the following values for R: 75, 140, 195, 240, 275, 300, 315, 320. We check by applying the formula $R = \frac{L\,W}{8\,D}$ for the central strain, which gives 320 as above. The strain in the top chord is obtained by taking successive values of x from 1 to 7, so that the strain in the first panel of the top chord is the same in that in the first panel of the bottom chord, and so on, the strain in any panel of the top chord being the same as that in the panel of the bottom chord next nearest the abutment.

To determine the shearing strain upon the ties and braces (the counterbraces will be spoken of hereafter), it will be necessary to ascertain in what way the weight is borne by these members. The top chord is kept at the proper distance from the lower one by the braces, and the lower chord with the load is suspended to the upper one by the ties. In this way the whole bridge and load are suspended by the ties to the braces, which may be considered as cranes or derricks.

We have found that the maximum shearing strain at any point occurs when only the longer of the two segments into which it divides the length of the truss is covered with the rolling load, and we have found the amount by which this maximum strain exceeds that produced at the same point when the whole bridge is covered by the load. We will therefore determine the strain on each tie and brace when the bridge is uniformly loaded, and then add this excess.

When the bridge is entirely covered, the whole weight of the 7 loaded panels between the end tie and the centre, is carried by that member, and by it transferred to the end brace. But, besides this, it carries half the loaded panel between this and the abutment, the other half being carried by the abutment. The total weight sustained by the tie, and by it transferred to the brace, is, therefore, that of 7.5 load panels. In like manner, the second tie and brace carry 6.5 panels, the third 5.5, and so on to the centre tie, which carries 1 panel, that is, half a panel from each side of the centre, while the centre braces carry only half a panel each, as they sustain the tie between them. Multiplying these coefficients by W'', we have for the tensile strain on each tie from the first to the centre, produced by a uniformly distributed load, the following values: 112.5, 97.5, 82.5, 67.5, 52.5, 37.5, 22.5, 15.

We obtain the proper augmentations from the formula $\frac{W'}{2\,L}m^2$, m being the unloaded segment at any point. In using this formula, it is important to ascertain the proper values to ascribe to m. In the present case, to obtain the augmentation for any given tie, we suppose the entire panel between it and the nearest abutment, covered with the rolling load which reaches thence to the furthest abutment. Half of this panel weight is born by the tie in question, and half by the tie next nearest the nearest abutment. The value of m for any tie is, therefore, the distance from the nearest abutment to the centre of the panel which the given tie closes. In this case the successive values of m are, 0.5, 1.5, 2.5, etc., up to 7.5. The value of the constant $\frac{W'}{2\,L} = 0.3125$, which multiplied by the squares of the above coefficients, gives the proper increment to be added to the values already obtained. We have thus far the maximum strains on the ties, 112.6, 98.2, 84.5, 71.3, 58.8, 47, 35.7, 32.6.

In a beam or girder, when $m = \frac{L}{2}$ the strain produced by the applied load equals $\frac{1}{8}$th of inch. If we applied this

rule to the present case, we should get a strain of 20 tons from the applied load, which, added to 4 tons from the permanent load, would give a total of 25 tons for the maximum strain on the centre tie. By the construction of the truss we are now considering, this amount is exceeded by half a loaded panel.

The strain in the braces are deduced from those in the corresponding ties by multiplying the latter by the secant of the angle which the braces make with the ties. That this gives a correct result is easily demonstrated by the resolution of forces. The secant is obtained by dividing the length of the brace by that of the tie. In the present case it equals 1.2; we have then for the maximum strains in the braces the values 135.1, 117.8, 101.4, 85.6, 70.6, 56.4, 42.8, 30. These strains are compressive.

We have now to investigate the subject of counterbraces, which are struts sloping in a direction contrary to that of the braces. In virtue of this definition, the braces of one half of a truss are counterbraces as regards those of the other half, the change of direction taking place at the centre of the truss, at which point the two middle braces abut against each other. If the truss be uniformly loaded, the centre is the point at which the greatest horizontal strain takes takes place. In a truss so loaded no counterbracing is necessary, and this fact points to the rule governing counterbracing in all cases.

Under all circumstances of loading, it is at the point of greatest horizontal strain that abutting braces or counterbraces, throwing the shearing strain right and left towards the two abutments, are needed. It has been already established that this point corresponds to the centre of equal moments of the reactions of the two abutments. When the bridge supports only its own weight, this point is at the centre. But the passage of a train, by unequalizing the reaction of the abutments, causes this centre of equal moments to shift from the centre of the truss. The point is now to ascertain how far it is possible for the weight of the passing train to cause this point to move from the centre of the truss, for beyond this point it will be unnecessary to provide counterbracing to resist the shearing strain. Let us examine the action of a train which advances upon the bridge, covers it throughout and moves off again. As the head of the train gets on the bridge, proportional parts of its weight go to each abutment and are added to the reaction of the permanent load. As these reactions are now unequal, they change the position of the centre of equal moments, which moves from the centre of the truss to a point nearer the advancing train. Counterbracing now becomes necessary as the train advances; the centre of equal moments advances to meet it, carrying the necessity for counterbracing with it. When the head of the train reaches the centre of the bridge, the counterbraces begin to be relieved in an inverse order to that which governed the progress of their compression, the one nearest the centre being the first and last compressed. When the bridge is entirely covered, it relapses into its previous condition of uniform loading, only with a heavier load. As the rear of the train gets on the bridge, the centre of equal moments begins to move forward from the centre of the truss in the same direction as the train, until the rear of the train reaches the centre of the bridge. From this time the centre of equal moments recedes again towards the centre of the truss. On this side also the counterbrace nearest the centre is the first to be compressed and the last to be relieved.

Bearing these considerations in mind, it is very easy to determine the last point at which counterbracing is necessary to resist a shearing strain. We suppose one half of the bridge to be covered with the rolling load, the weight of which is supposed concentrated at the centre of gravity of the half truss. The total reaction of each abutment is then ascertained, and the centre of equal moments calculated. Between this point and the nearest abutment, no counterbracing is required to resist the shearing strain. In our example, the reaction of each abutment from the truss alone is 40 tons. If half the bridge be covered with the rolling load, the abutments will bear an additional weight of 80 tons, of which 20 tons will go to one, and 60 to the other. Adding, we have 60 tons and 100 tons respectively for the reactions of the abutments. The equation for equal moments is therefore $x\ 100 = 60\ (L - x)$, whence $x = 6$. That is,

the last counterbraces are required at the distance of 6 panels from each abutment, in our example, which would give two counterbraces on each side of the centre of the truss.

The amount of compressive strain in these two counterbraces, is determined by the following considerations, which, as they involve some of the most important principles of bridge strains, should be closely followed. Under the action of a uniform load, these two members would sustain no compression; on the contrary, if they were so attached to the chords that they could act as tension members, or ties, they would sustain a tensile strain, the one nearest the abutment, *a b*, sustaining one and a half panels, and the other one, *c d*, one half of a panel. If we suppose half the truss to be covered with the rolling load in the manner mentioned, its weight would tend to compress the two counterbraces. But no member of a truss can at the same time sustain or tend to sustain tension and compression, and when both are brought to bear upon it, the actual strain sustained is the difference between the two. Thus, if a certain member was subjected to a strain of 10 tons in tension, and 20 tons in compression, the actual strain sustained would be 10 tons compression. In the present case, the permanent truss weight brings a tensile strain of 1.5 *w* on the first, and 0.5 *w* on the second counterbrace, and we must see what compressive strain the weight of the train load brings upon them, and take the difference as the actual strain. To do this, we must take each panel weight of the rolling load separately, and ascertain its effect upon the member in question, the sum of these separate strains being the total compression on the counterbrace.

Each tie sustains one panel weight of the rolling load $= W^1$. The first panel weight (W^1) on the tie nearest the abutment, sends $\frac{1}{16}$th or $\frac{1}{L}$ of its weight through the truss to the other abutment. The second sends $\frac{2}{L}$, the third, $\frac{3}{L}$, the the fourth $\frac{4}{L}$, the fifth, $\frac{5}{L}$, and the sixth $\frac{6}{L}$ of its weight through the truss in the same way, and these all act compressively upon *a b*. The sum of this series is $\frac{21W^1}{L} = 13.12$ tons. Subtracting the tensile strain of 7.50 tons, we have a net compression of 5.62 tons on *a b*. For the strain in *c d*, we must take one more term of the series, and we have $\frac{28\ W'}{L} = 17.50$ tons. Subtracting the tensile strain of 2.5 tons gives a net compression of 15 tons on *c d*. These values must be multiplied by the secant of the brace angle.*

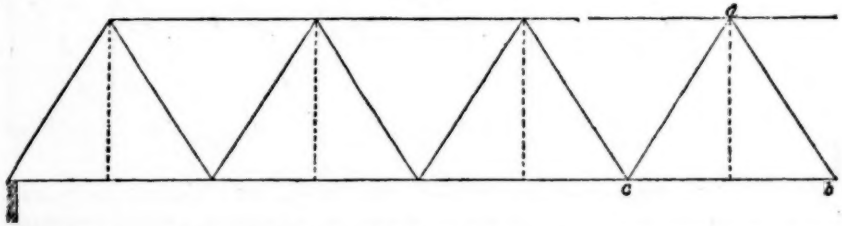
The above investigation shows at what points counterbraces are required to resist the shearing strain of the travelling load. There are other considerations, however, which seem to point to the expediency of counterbracing a truss throughout. There are two qualities requisite in a bridge—strength and rigidity. So far we have considered only the former, though the latter is scarcely less important in structures which, like those in question, are destined to be permanent within the limits of natural decay. All trusses of long span tend more or less to deflect, and if any such structure be designed to sustain a permanent load only, its deflection is generally a matter of but little moment. But when, as in the case of a railroad bridge, it has besides to sustain a travelling load alternately applied and withdrawn, the case is different, for the deflection of the truss under the application of the weight, is followed by an upward spring on its withdrawal. In other words, the tendency of the rolling load is to induce *play*, which in a built structure leads to shocks at the joints, which become eventually loosened and unserviceable. When a truss deflects under weight, the panels are distorted from their original rectangular shape into lozenges, by the sliding of the chords upon the web, like a parallel rule. This distortion cannot occur without the braces yield by crushing or flexure, for the diagonal of the lozenge in the direction of the brace is shorter than that of the rectangle which it originally formed.

* The strains produced in these members by the rolling load, may also be determined as follows. The weights sustained between *a b* and the end brace *e f* = 6 panels. Of this, $\frac{3.5}{16}$ are sent to the right abutment; therefore the strain on *a b* $= \frac{21W'}{L}$, as before. The weight between *c d* and *e f* = 7 panels, of which $\frac{4}{16}$ go to the right abutment. The strain on *c d* is therefore $\frac{28W'}{L}$ as before.

The braces are therefore the members of the web which oppose deflection. The ties are unaffected by the change of form of the panels while the counterbraces are loosened, as the diagonals in their direction are longer in the lozenge than in the primitive rectangle. When the weight which caused the deflection is removed, the braces are relieved, and the truss springs back against the counters. If, however, while the weight is on the bridge, the play of the counters be taken up, the truss is prevented from recoiling when the weight is removed, and a great degree of rigidity is secured. If the ties of a Howe truss be shortened by screwing up the nuts, the whole truss rises to a camber, and both braces and counterbraces are compressed. If sufficient weight be now brought on the bridge, it will settle to a straight line, compressing the braces still more, and relieving the counterbraces. If when in in this position the counterbraces be tightened up by the introduction of some sort of packing, the truss will be held down to the straight line after the removal of the weight. The strain thus brought on the counterbraces is not cumulative, but is simply that due to one panel weight of the rolling load on each counterbrace throughout the truss,

We will now take up some other forms of straight trusses, and see how their different forms affect the system of calculation adapted for the Howe.

FIG. 5.



The Warren girder, one-half of which is shown above, is trussed with isosceles triangles. Those members, the tops of which incline towards the centre, are braces, and those sloping in the contrary direction are ties. When the panels are very long they are supported by vertical ties, as shown by the dotted lines in the figure. We will first examine the case where these are omitted. In either case the strains in the chords are calculated as in the Howe truss, only for the lower chord, the values of x in the formula

$$\frac{W}{2DL}(Lx - x^2)$$

should be from 0.5 to 3.5, and for the upper from 1 to 4. The point at which counterbracing ceases to be necessary to resist the shearing strain of the rolling load is also calculated as before.*

When the bridge is covered throughout by the rolling load, the ties and braces, commencing with those next the abutment, bear respectively the weight of 3.5, 2.5, 1.5 and 0.5 loaded panels. The increments of strain due to the displacements of the rolling load, are obtained from the usual formula, by giving to m successive values of 0.5 to 3.5. These values must be multiplied as before, by the secant of the brace angle. The truss is counterbraced by so arranging the ties and braces that they may sustain both tensile and compressive strains. Assuming the same weights and length of truss as before, we find the point up to which the counterbracing must be carried, at a distance of 3 panels from the abutment. The brace $a\ c$ will therefore be subjected to a certain tensile strain from the action of the rolling load. The amount of this strain is expressed by the equation

$$\text{Sec. } \theta\ (W\left(\frac{1}{L}+\frac{2}{L}+\frac{3}{L}\right)-0.5\ W)=12 \text{ tons.}$$

The tie $a\ b$ sustains the same strain in compression.

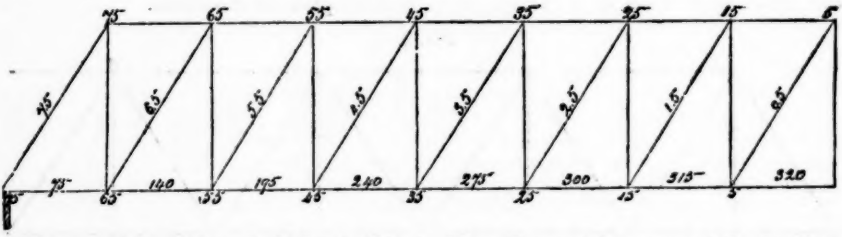
When the vertical ties are added, the braces bear more weight than the ties which slope from their tops. The main ties bear respectively weights in loaded panels, represented by the coefficients

* It may here be stated, that this point is obtained for all descriptions of straight trusses, however the web may be constructed, by the same reasoning as that employed in the investigation of the Howe truss.

3.25, 2.25, 1.25, and 0.25, with values for m in the formula for increments from 0.75 to 3.75. Each vertical tie bears the weight of half a loaded panel, which it transfers to the brace from which it hangs. The braces sustain, therefore, weights of 3.75, 2.75, 1.75, and 0.75 loaded panels, with increments obtained by giving to m successive values of 0.25, 1.25, 2.25, and 3.25. The compression on the tie $a\ b$ from the rolling load is 15 tons as before.

We have now to consider a class of trusses known as compound trusses, in which the web is composed of two or more systems of trussing, crossing each other. In calculating these trusses, the formula employed so far for determining the strain in the chords is inapplicable without a degree of modification which would render its use tedious. The method employed by Mr. Stoney (Stoney on Strains, vol. i., p. 84) is probably the best that can be used in such cases. He deduces the strain in the chords from the vertical strain in the inclined members of the web, and as his system is equally applicable to simple and compound trusses, we will first investigate it in reference to the Howe truss already calculated.

FIG. 6.



The principle of the calculation is this: the strain in the chords consists of the horizontal components of the vertical strains in the inclined members of the web, and is obtained at any point by the addition of all such horizontal components as occur between the given point and the nearest abutment. These horizontal components are obtained by multiplying the vertical strains by the tangent of the angle θ which the inclined members make with the vertical; as the maximum strain in the chords occurs when the bridge is covered with the rolling load, the first step is to ascertain the amount of vertical strain on the braces when the truss is so loaded, and to write it down upon a sketch of the half truss, as shown in Fig. 6. Keeping the same weight and dimensions as before, we find the value of the constant $w'' \times$ tang. $\theta = 10$ tons. We write the horizontal component of each brace strain, obtained by multiplying the vertical strain by the constant 10, at its apexes, and by successive additions determine the strain in each panel length of the top and bottom chords, as shown in the figure. The results agree with those obtained by the calculation by moments.

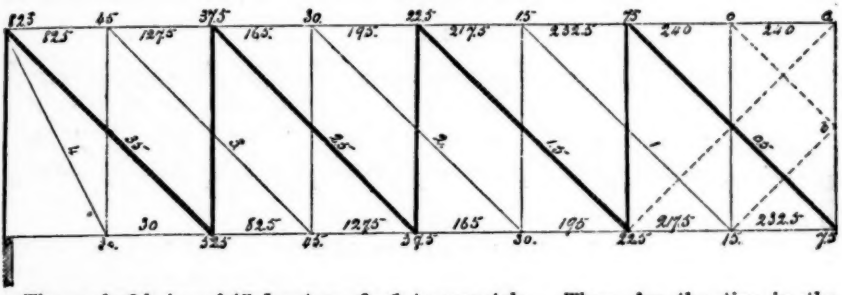
We will now take some of the leading styles of compound trusses, beginning with the Linville.

This truss is composed of two systems of triangles, crossing each other, as in the figure, which shows half the truss. Each system bears half the strain which would come upon it if it alone formed the whole trussing. We will assume a truss bearing the same weight as before, and of the same dimensions, except that the depth shall be 25 ft. In the figure, one system of trussing is drawn with heavy lines merely to distinguish it more plainly from the other. The upright members are posts or braces, the inclined, ties.

The vertical strain on each tie is ascertained by taking each system separately, and supposing it to sustain half weights. It may also be done by a direct estimate, thus: The first tie from the centre, of the heavily marked system, bears obviously the weight of half a panel, that is, half the weight of the segment of the lower chord, comprised between its foot and the centre post. The other half is borne by the neighboring tie of the light lined system. This last bears besides half of the segment between its foot and that of the heavy lined post next behind it. These

two halves constitute the one panel allotted to it in the figure. The next heavy lined tie bears the other half of this panel *plus* the half panel next behind it, *plus* the half panel transmitted to it through the heavy lined post which rests on its foot. The next light lined diagonal supports in like manner two half panels, *plus* the panel transmitted to it through the post resting on its foot, the whole making up the two panels allotted to it in the figure. A similar process of reasoning verifies the rest of the weights allotted in the figure.

FIG. 7.

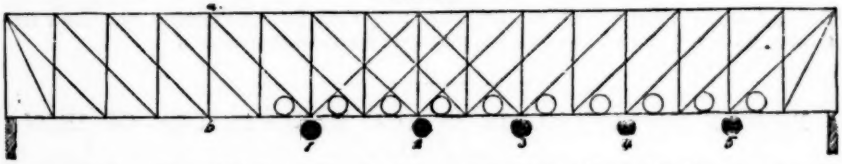


The angle θ being of 45 deg. tang. $\theta=1$, and the constant tang. $\theta\ w'=15$ tons. The end ties of both systems are connected with the end post, as shown in the figure. The tie bearing 3.5 loaded panels transmits a horizontal strain of $3.5 \times 15 = 52.50$ tons to the first panel length of the upper chord, while that bearing 4 panels transmits only $4 \times 7.5 = 30$ tons, to the same member, its tangent being only 0.5. The additions are made as by the figures.

The maximum strains on the ties and posts are found by considering each truss separately. Thus, for the ties in the heavy lined system, we have in the formula for increments $\frac{W' m^2}{2 L}$, $w'=10$, $L=8$, and m = successively 0.5, 1.5, 2.5, and 3 5. The increments so obtained are added to the panel weights already determined, and multiplied by sec. θ for the ties.

There is another method of calculating these maximum strains, which may sometimes be useful in checking results obtained by the above process. This consists in ascertaining the strain exercised

FIG. 8.

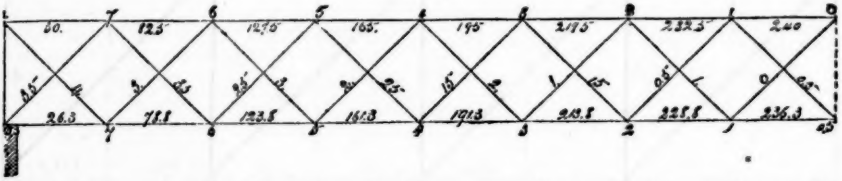


upon each tie and post by the rolling load when at its position of maximum effect, and adding this to the strain produced by the bridge weight. For instance, let it be proposed to ascertain the maximum strain on the post $a\ b$ and the tie $a\ c$. The maximum strain from the rolling load will occur when the truss is loaded from the tie in question to the last tie of the same system, as shown in the figure by the light balls. As each tie of the system to which the members we are considering belong, sustains one half of each of the panel weights adjacent to it, we may suppose the weights resting upon the lower chord to be transformed into those drawn below it in black in the figure. We will now ascertain the amount of shearing strain which each weight sends through the unloaded segment, and their sum will be the maximum strain on $a\ b$ and $a\ c$, from the action of the rolling load. No. 1 sends $\frac{1}{16} w'$; No. 2, $\frac{8}{16} w'$; No. 3, $\frac{6}{16} w'$; No. 4, $\frac{4}{16} w'$; and No. 5, $\frac{2}{16} w'$; adding we obtain $\frac{21}{16} w' + 1.5\ w$ for the maximum shearing strain in the post. Multiplica-

tion by the secant of the tie angle gives that on the tie. An inspection of the above descending progression suggests an easy rule for determining the strains by this method for any tie or post. Take the number of panels in both systems (10 in the present case) in the loaded segment, and make it the first term of a decreasing arithmetical series, of which the ratio is the number of systems in the truss (2 in the present case). The sum of this series multiplied by the rolling panel load and divided by the number of panels in the truss gives the maximum strain in the given members from rolling load.

A counterbrace is needed in the position of the dotted line *a*, 22.5, capable of resisting a tensile strain equal to

FIG. 9.



sec. θ ($w' \frac{9}{4} - 0.5\ w$). The heavy lined tie which it crosses is susceptible of receiving a compressive strain of equal amount. The dotted line *b*, 15, sustains a tension of sec. θ w', and *b*, *o*, an equal compression.

Above is shown half of a lattice girder, 80 ft. long, 5 ft. deep, braced with two systems of rectangular trussing; load as in previous examples, traversing the lower chord. We assume the following values:

w = 2.5 tons, panel weight of truss.
w' = 5 tons, panel weight of travelling load.
($w + w'$) tang. θ=7.5 tons.
L=16.

Reasoning as before, we get the strains shown on the above diagram. To obtain the maximum tensile and compressive strains on the ties and braces, we may use either the method by series, or the method by increments, which agree very nearly in their results. In the latter we have L = 8, w' = 5 for both systems, and successive values for m of 0.5, 1.5, 2.5, and 3.5; for the system, 3.5, 7, 6, etc., and of 0.25, 1, 2, and 3 for the other. The summation of series is operated as usual.

Counterbracing is needed from the point 2 to the centre. The brace 1.2 sustains a tensile strain of

$$\text{Sec } \theta \left(\frac{6\ w'}{8} - \frac{w}{2} \right) = 3.5 \text{ tons},$$

and the brace 0.1 one of sec. $\theta\ w' = 7$ tons.

The above example is the same as that given by Mr. Stoney in his treatise on strains, Vol. I., page 111, with the exception that in his example the load traverses the lower chord.

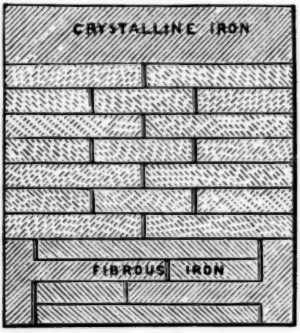
RECENT IMPROVEMENTS IN THE MANUFACTURE OF IRON RAILS.

From "The Engineer."

The superiority of steel rails to iron, which is now generally proved to consist chiefly in perfect homogeneity of the wearing surface of the railhead, causes us to regard with much interest every effort to obtain a similar homogeneity in the manufacture of iron rails; for, leaving the required safety in steel and iron out of the question, as a matter of absolute necessity for both, it is from the homogeneity more than from the hardness in the steel that rails of this material derive their excellent results. To prove this in a chemical way, the small amount of carbon, about one-third per cent., compared with the increased stiffness when steel rails are tested under the lever, or ball, of only 25 per cent., as compared with iron rails, leads us to conclude that if ordinary iron rails were made as homogeneous as steel, they would stand very nearly an equal wear and tear. The well-known complaint of

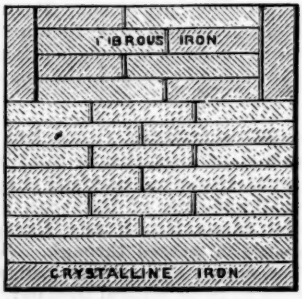
lamination and so-called "soft places" in the wear of iron rails proves them an early failure as compared with steel rails, and the increased demand for the latter is, therefore, not to be wondered at. This increased demand seems at present to have exceeded the means of supply, for we are told that the steel rail makers are nearly all full with orders for two years to come; consequently the railway engineer who requires good wearing rails for heavy traffic is placed in the difficult position of not only having to pay an increased price for steel rails, but also having to wait for them, if he can get them at all.

Fig. 1.



Until the supply increases to meet the demand, we must look for a retrogression to superior iron rails from those who can neither afford to pay nor to wait for steel rails. It is these circumstances that bring our attention to a patent rail pile by Messrs. Richardson and Sons, of West Hartlepool, of which we annex a sketch:—

Fig. 2.



The annexed diagrams show two methods of forming the rail pile, No. 2 being that in universal use, No. 1 the patent pile. It will be seen that the old pile (diagram No. 2) is, and must necessarily be built upon the slab of crystalline iron which forms the head of the rail, and must be placed in the heating furnace in the same position, viz., the slab on the bottom, which is the coolest portion of the furnace, the fibrous iron uppermost, exposed to the most intense flame; and in this position it must remain until the several pieces of iron composing the pile are welded together so as to allow the pile to be turned over. The result of this treatment is, that in many cases the fibre of the flange is destroyed, whilst the head is imperfectly welded, and there is produced a brittle rail with a laminated and consequently bad-wearing head. In the patent pile the treatment is entirely reversed, the fibrous iron to form the flange being placed on the bottom of the heating furnace, and thus preserved from the intense heat which is destructive to fibre, whilst the slab which forms the head of the rail, being placed uppermost in the hottest flames, becomes perfectly welded, and the rail produced possesses the maximum of strength combined with perfection of wearing qualities.

The side pieces A, A, are made direct from the crop ends when cut off from the rail, which adds to the cheapness of make. Large quantities have already been made, with the result of better welding in the rail head and more fibrous flanges, which will give a better wearing rail and no breakages. The patent in itself is of little novelty, and we could hardly answer for makers being able to hold it, or at any rate share any royalty from it, for there are other works in the North—such as Darlington and Britannia, and Ebbw Vale, in Wales—which have also constructed a a pile charged in the furnace with the slab up, although in a different way, yet with similarly good results.

We consider this one of those practical improvements which is of the greatest importance for maintaining a good quality, and therefore worthy the notice and material support of railway engineers. We should not undertake to say how much more should be paid for such rails as compared with those made in the ordinary way, and charged with the slab down, because experience will have to prove the degree of their superiority; but for extra

rails made to specification we should certainly recommend it, even should the makers ask 10s. more per ton for inserting this improvement alone. The so-called improvements generally tend to deteriorate the quality on an increased make and reduced cost of production; indeed, the history of rail making from the commencement up to the present time shows this, for why do we so often hear the remark that iron rails made nowadays are not half so good as those made a dozen years back, and nobody can contradict it; but the answer is that those rails cost twice as much as these do now, and speaks sufficiently as to the nature of the improvement.

The question of mechanical puddling, by which a bloom could be obtained big enough to form the whole rail—or at least the entire rail-head—without any seams from piling iron together, will be looked upon with the greatest interest, and we hope that the commission from the Iron and Steel Institute now in America investigating the process of Danks' rotary puddling furnace will on their return be able to effect changes which will lessen the labor of puddling and improve the wearing qualities of our rails. Meanwhile we consider the mode of working the rail pile with the slab up to the best next means of obtaining a thoroughly homogeneous rail-head and a tough fibrous flange. We believe the Americans, who now make half the rails they require, have already adopted this mode of working; and indeed, the complaints of English iron rails on some of their roads with heavy traffic are too serious to be overlooked by the rail-making interest in this country.

THE ISTHMUS OF SUEZ.—An important work on the piercing the Isthmus of Suez is being published in Paris; it is a detailed description of the works, and of the machinery and plant employed, and of the processes and materials used in the actual construction of the canal. The programme of this book states that its object is to detail and reproduce by its drawings all the technical elements which were introduced in the progress of the work. This is the first time that these elements have been thus grouped, the numerous volumes which have already been published bearing on the political, picturesque, or commercial aspects of the work of M. Ferdinand de Lesseps.

It is M. L. Monteil, engineer of the Suez Canal Company, who has been attached to the gigantic undertaking since 11 years, who has undertaken this publication. The text will be as concise as possible; with the history of the work and the description of the drawings it will give in detail all prices, and the performance of each item of the plant. There will be 300 plates engraved on copper, giving drawings in detail of the works and the machinery. The work will be divided into ten series.

1. Towns and encampments. Plans of the maritime and fresh-water canals. Geological sections of the Isthmus, and profiles of the ship canal.
2. Distribution of fresh water.
3. Jetties, lighthouse, and works of construction.
4. Services of transport.
5. The small dredging machines; the application of the endless bands and spoil distributors.
6. Dredging machines employed in the canal; spoil boats and lighters.
7. Dredging machines, elevators, etc.
8. Dry cuttings. Wagon and engine shops.
9. Repair shops.
10. Materials for maintenance and lighting.

It will be seen that it promises to be a considerable work. All the materials for the text and the plates are ready, and at present they are being prepared for publication. This work, which will confer lasting honor on its author, is intended to render special service to those engineers who may be called upon to study or carry out great undertakings of public interest analogous to the Suez Canal. But it will interest all those who wish to appreciate the efforts made unceasingly during 15 years to open a new route to the commerce of the world.—*Engineering.*

EUROPEAN PRODUCTS IN JAPAN—The "Japan Times" says, that in the interior of Japan there are to be found shops exclusively for the sale of European goods, and that where few, if any, Europeans have visited or passed through. Soaps, perfumes, clocks, colored engravings, and beer seem to be in general demand, while some shops deal exclusively in tables and chairs after the European fashion.

SEWAGE IRRIGATION.

From "The Engineer."

The chief points to be attended to by agriculturists in a practical sense, if they desire to reap that which they sow, are undoubtedly the manuring of the land, the draining of it, and a skilful and judicious rotation of crops. Most farmers understand the first, so long as it does not deviate from the stereotyped methods practised from time immemorial, but, comparatively speaking, few the second and third. Yet, upon an accurate comprehension of these essential branches of the subject, a due appreciation of their paramount importance, and a regular and systematic adoption of them in practice, depends unquestionably the permanent fertility of the soil. It is true that land is occasionally met with, which, from a peculiar geological formation and other favorable influences of situation, is so exceptionally fertile as to require but little manure. It is not, however, the lot of one farmer in a thousand to have his tent pitched among these prolific oases. In many instances, if the land does not produce the results which may be fairly expected of it, the usual cry is that it wants more manure, when, in fact, it may be already choked with it. Nevertheless more manure is applied, while the other two points to which we have drawn attention are scarcely thought worthy of notice, and thus the attempt is made to compensate by the wholesale unscientific application of the one for the total neglect of the others. The soil is stimulated or forced to do that which it would accomplish spontaneously with a trifling assistance, were it treated in a proper and scientific manner. The mania which some farmers have for curing all the evils or shortcomings of land by an unlimited use of manure, was well demonstrated when the utilization of sewage by irrigation was first introduced. Many owners and proprietors of land tried the system on a small scale, and, as might be expected, the result was a complete failure. They imagined that nothing more was required than to deluge the land with the new fertilizer; and that magnificent crops would follow as a matter of course. But with one exception, namely, that of grass, magnificent crops did not follow, even when the method was tried on a large scale, and by those who understood as much of the principle as was understood at that time. It is very unfortunate that grass should evince such an avidity for sewage, for it has led to a very reckless mode of distribution, which has been adhered to in the case of other crops with the most unsatisfactory results. Had grass crops demanded the same care and discrimination in the application of sewage as the cereals and roots, the system of sewage irrigation would be in a far more advanced stage, both theoretically and practically, than it is at present.

Hitherto the principle of sewage irrigation has been regarded as a superficial irrigation only, the fertilizing fluid not being supposed to penetrate into the ground much deeper than the roots of the plants and crops growing upon it. Hence arises the great, and it must be acknowledged in some instances, the insuperable difficulty of carrying out the irrigation principle. Obviously a very large area of land is required upon which to utilize the sewage. Without going into the merits or demerits of the various proportions, which different authorities have laid down ought to obtain between the numerical strength of the inhabitants of any given town and the number of acres necessary to utilize the sewage of that town, it may be assumed that the average which places the ratio at 100 people to the acre is a fair one. If a farm were entirely laid down in grass this average would be less than that required; but as experience has shown that the sewage of a town cannot be remuneratively utilized by its application to a single crop, it is a correct one under general conditions. Supposing, however, that it could be put at 150 persons to the acre, then, taking the population of a city at 500,000, over 3,000 acres would have to be devoted to the purposes of sewage utilization. This quantity of land is not acquired without some difficulty, more especially when it is borne in mind that there are several conditions to be fulfilled with respect to situation, levels, and physical contours, upon which altogether depends the financial success of the undertaking. As a rule, a certain quantity of land can gen-

erally be obtained for irrigation purposes, but this amount is very limited; and moreover, for many reasons, may not be well adapted to the end in view. Take the case, for example, of a town lying in a hollow, as a vast proportion of towns do. If there are no fields contiguous thereto at about the same level, it becomes necessary to pump the sewage up to a certain height before it can flow over the land situa ed at a higher elevation. It must be borne in mind that while we acknowledge these difficulties attendant upon sewage irrigation, which have retarded the development of the principle in its integrity ever since it was practically applied, they constitute no argument against its value, which has been demonstrated too convincingly to admit of any doubt in the mind of any disinterested and impartial judge.

From what has already been stated, it will be manifest that if the irrigation principle could be applied to a much smaller area of land than is more generally considered requisite, a considerable gain in every respect would be obtained. It would be not only possible, but easy, to procure a minimum quantity of land in many instances where the maximum, or what is now considered the necessary, quantity is unattainable. The problem connected with the utilization of sewage by irrigation is to utilize the maximum quantity upon the minimum area of land. It may be urged that this has been virtually accomplished at Craigintenny for many years past; but the soil there is of a peculiar nature, and not often met with. Besides, the correct definition of the term "utilization" does not signify a mere deluging of fields of grass with sewage, but the application of it in such a manner as will yield the most remunerative return under the circumstances. It must not be forgotten that the purification of the effluent water is a point to be attended to, as equally essential with the utilization of t ie sewage. It is, in fact, more so; for, as the effluent water must sooner or later find its way into some stream or water-course, care must be taken that the contents are not polluted thereby. It has been before remarked that under the present system the sewage penetrates but an inconsiderable depth into the soil; but were it caused to penetrate much deeper, as it would always be in contact with it, the process of purification would still go on, and the same results obtained, with a considerably less superficial area of soil. In a word, the purification of the sewage would not depend upon the superficial but the cubical contents of the land. This is the plan proposed by Mr. Denton, and it deserves serious consideration at the hands of all those interested in this great question. It will at once be seen that it signifies deep drainage of the land, as it is proposed to allow the sewage to penetrate to a depth of from 4 to 6 ft. before passing off through the drains. This plan possesses several features to recommend it. The first is that a much smaller number of acres will suffice for the purification of the sewage of a town or district; the second, that deep draining of the soil, so much neglected by farmers, will be imperative, and the third that the land will be more thoroughly manured than by the present process of superficial irrigation.

The expense of carrying out this method will undoubtedly be greater than the cost of that now in use; but, provided the undertaking pays, that is not an insuperable obstacle. Neither would the cutting of the trenches and the laying of the necessary pipes be so difficult or so expensive a matter as might at first appear. Messrs. Fowler have machines expressly designed for these purposes. Their patent "knifer" will open ground at almost any depth; and in heavy clay soils, where it is not advisable to bring the subsoil to the top, the machine can be driven through the ground without materially disturbing the surface. The next operation, that of laying the pipes, could be accomplished with equal facility by means of their patent draining plough, which is adapted to be worked by the ordinary plough engine. It can be used as a mole plough, and will lay pipes in stiff clay soils at a depth of 4 ft. with perfect ease and safety.

If we examine into this proposed mode of purifying sewage, in order to produce a pure, clear, effluent water, the nature of the soil must be taken into account. Sewage must be purified in a double sense, mechanically and chemically. By the present irrigation system the former is effected partly by filters, extractors, and some other mechanical agency, and partly by filtration to a small depth through the soil, and the latter by the assimilating powers of the plants, with the roots of which the liquid is bro ght into contact.

If, however, we irrigate the land cubically instead of superficially, a large portion of the sewage must be purified both mechanically and chemically by the soil alone. The question, then, is: are all soils capable of acting in this double capacity? Certainly not. A peaty soil is well calculated to act both as a filter and a chemical purifier, but many others will not effect the double object. It cannot be too carefully kept in view that although water may be completely deprived of all its mechanically suspended impurities, and to all appearance be perfectly pure and clear, it may, nevertheless, be chemically exceedingly impure, and totally unfit to drink. It is notorious that water slightly contaminated with sewage has not only a clear, sparkling appearance, but, owing to its saline ingredients, is rather agreeable than otherwise to the taste. It is alike deceptive to both the eye and the palate. Accurate chemical analysis is the only test to be depended upon in determining the purity of water. Another point to be kept in mind with reference to the proposed mode of irrigating the land to the depth of several feet, is whether it would not after a certain time, become so completely saturated with sewage as to be incapable of any longer fulfilling the duty required of it. Although experience has hitherto furnished us with no information on this head, yet there is no question that such would be the case. Manifestly the land would be literally a filter for the sewage. All filters, from the domestic specimens to the beds necessary for water-works, become clogged after a certain time, and must be cleaned out. The time they will last without cleansing depends altogether upon the character of the liquid they have to filter, and the case is the same with the land. Accordingly, as the sewage is more or less charged with solid ingredients, so will the land become foul and clogged in a short or a long period. But the land, when in this condition, would have to be cleansed, which could only be accomplished by abstaining from any further irrigation. In the interval which the soil would require to return to its normal condition—which would certainly be two or three years at least—the sewage, which is continuous in its discharge, would have to be turned on to some other land. It, therefore, is by no means certain that the total quantity of land required in 10 or 20 years would be so very much less than that which would be necessary under the present system of superficial irrigation. One thing is certain, that if this method was once adopted, and more land was required, it would have to be obtained at all hazards, even if houses had to be pulled down to clear the ground.

THE EUPHRATES VALLEY RAILWAY.

From "Journal of The Society of Arts."

The report from the Select Committee on the Euphrates Valley Railway has been published, with the evidence of several distinguished Oriental travellers and eminent engineers, upon the route best fitted to secure a direct communication between this country and our Indian Empire. The Committee have, for the present, agreed to report to the House of Commons the evidence they have gathered, leaving the many important questions raised until the sittings can be resumed at the commencement of next session. Apart from certain minor questions of more or less relative consequence in regard to the direction which the line of railway should follow, we learn there is a divergence of opinion upon the desirability of using the Black Sea or the Mediterranean as the basis of operations. These points were clearly explained at the outset by Sir Henry Rawlinson, the first witness called, who speaks with the authority of personal knowledge, gained by 12 years of residence and travel in Turkish Arabia. We learn from his description that several routes have been recommended which possess certain advantages, and are therefore deserving of the consideration of the Committee. The first is a route which has been proposed by the Turkish Government, and for which the Porte gave, or offered, a concession as long ago as 1866 or 1867. This was intended to connect Constantinople with the Persian Gulf. It was to start from Scutari, opposite Constantinople; then it passed along to Izmid, Kutayich, Kara-Hissar, Kumèh, and Kaisarich to Aleppo, and then

down the Valley of Euphrates to Bagdad and Bassorah, and from Bassorah to the head of the Persian Gulf. The distance was estimated at 1,700 miles, including a branch from Aleppo to Scanderoon. It was 800 from Constantinople to Aleppo, including the Scanderoon branch of about 120 miles; and it was 900 miles from Aleppo to the Gulf. The second is what is generally called the "Andrews" line, or the well-known Euphrates Valley route, which is the same as the lower portion of the route described, but the essential difference being that the terminus is at Scanderoon instead of Constantinople. The distance is estimated at 850 miles, whereas it should be in reality 1,000 miles. The third route, which has been strongly recommended to the Government by Col. Herbert, the present political agent in Arabia, would also leave the Mediterranean at Scanderoon, but it would subsequently pass by Aleppo across the Euphrates at Bir or Orfah, which is the ancient Edessa, and so on to Diarbekr, Nisibin, Moosul, and then along the Tigris to Bagdad and B ssorah. This route would be 100, or perhaps 150 miles longer than the Euphrates Valley line, as it makes a considerable detour to the north-east, but it has the advantage of passing through a number of large cities and centres of trade, and lying generally among settled and populous districts. These are the three routes which exist between the Mediterranean and the Persian Gulf.

There are, besides, two or three routes from the Black Sea which ought to be considered. There is, in the first place, a route which has recently been advocated. It leaves the Black Sea at Jereboli, near Trebizond; it crosses the mountains to the Valley of the Euphrates, at Erzingam; it then takes a steamer and passes down the Euphrates to the point nearest to Diarbekr; it then crosses to Diarbekr and follows the Tigris down to the sea by steamer. This would be about 950 or 1,000 miles, partly water and partly railway, but the water communication would be only practicable for a few months in the year, and then only downwards. There is another route which leaves the Black Sea at or near Samsun, and follows the high road to Sivas; from Sivas it would follow a line by Malatieh and Diarbekr, and from Diarbekr it would follow Colonel Herbert's route to Bagdad and Bassorah. This would be about 1,000 miles in length. There is another route also from the Black Sea, although the project has not attained any substantive form, and that is a line from Trebizond to Erzeroom, across the mountains, and from Erzeroom to Van, and then down the Betissú to the Tigris, above Moosul, and from that point along the same line as the last route. This line would cross the range of the Taurus in about its most difficult and impracticable position, and would be impossible to effect, the country being cut up by a succession of precipitous ravines, mountain torrents, and impracticable defiles. Other lines have been projected connecting Europe with India, but this question involves much larger considerations than those affecting the mere limited question of connection between the Mediterranean and the Persian Gulf. There are, according to Sir Henry Rawlinson, three great lines which have been projected to connect Constantinople with India. The first would pass Constantinople along the northern or high road to Erzeroom; from Erzeroom, it would cross the Persian frontier to Khoi and Tabreez, and so on to Teheran, the capital of Persia; from Teheran it would pass to Shahrood and Mushed; at Mushed it would run south-east to Herat, and so on to Kandahar, and through the Bolan pass to Shikapoor and Sukkur, where it would join the Indus Valley base. The length of this line would be nearly 3,000 miles, which is not quite so much as the line which connects Sacramento with New York, and which distance is traversed in a week. The second line also leaves Constantinople, and follows the central route through Asia Minor, or, as it is now generally called, "the telegraph route," being the line along which the Turkish wires which carry our messages to India are placed; it passes by Angora, Yusgat, Sivas, Diarbekr, and Moosul to Kifri, which is the nearest point to the Persian frontier on that line, and where our telegraph turns off to Persia. From Kifri it would cross the Persian frontier, and ascend through the "gates of Zagros" to Kermanshah, and so on by Humadan to Teheran, where it would join the route contemplated to the Indus Valley. The length of this line would be about 3,200 miles; it presents engineering difficulties at two points, namely, the descent of Taurus and the ascent of Za-

gros, but it has many compensating advantages. There is another, or third route. From Constantinople, it would follow the same line, as far as Bassorah, as No. 1 of the limited routes; that is to say, it would pass by Kutayïeh and Kumèh to Aleppo, and along the Euphrates Valley to Bagdad and Bassorah, being absolutely the same as the line proposed by the Porte. From Bassorah it would circle round the northern and eastern shores of the Persian Gulf, passing by Bushire and Bunder Abbas, and would then follow the coast of Mekran to Kurrachee. This would be somewhat shorter than the upper line, about 2,900 miles, and from Bassorah, along the shores of the Persian Gulf, with the exception of Bushire, there is not a town worth speaking of, and a very scanty population—that is to say, throughout the whole distance from Bassorah to Kurrachee.

The evidence given by Colonel Chesney bears more especially upon the advantages of the Euphrates Valley line in particular, and the nature of the country through which it passes. He observes that the route from Trebizond by the Tigris would be highly advantageous to Russia, but of little or no service to this country. The port is an open one, and therefore highly objectionable, with steep mountains behind it, and the Taurus beyond them. In the event of a war with Russia, and Russia having the command of the Black Sea, she would be able to shut up the terminus of the railway upon the Black Sea; whereas, if the terminus were on the Mediterranean, England would have the command of it, as being easily defensible, and there would be an excellent port at which to land an army. In his opinion, therefore, the line by the Euphrates from the Mediterranean is the only one desirable for the English nation to construct. The chief engineering difficulties occur at the first stage from the sea, in the 15 miles traversed from Swedia, or Scanderoom, to Antioch; all the rest is easy. There would not be a single tunnel or cut to make. The population along the proposed line is very considerable. The Arabs would number between 2,300,000 or 2,400,000; they come in the summer, and go away again; therefore, there is a large population—several towns with considerable commerce. A great traffic might be established with this country from points where there is already a large trade. The imports through Aleppo are upwards of two millions, coming from the line of Arabia, and the exports are not far short of the same amount. The Tigris has its commerce also, but the commerce of the Tigris is not so great as that of the Euphrates. The land is favorable to the growth of cotton, linseed, corn, and everything which is produced in India. In the early spring, clover and grass may be seen growing 9 ft. in height. It is the finest alluvial soil in the world, and is much more fertile than the land in the valley of the Tigris. There is an existing traffic passing by means of the caravans, and there has been a communication through Arabia since the time of Abraham; it has never ceased. The caravans go through, and hardly ever meet with any difficulty from the Arabs, except a slight payment, which the sheik expects. There would be no obstruction, and labor would be readily obtainable for the construction of the works along the line. With regard to climate, the deaths from fever and ague are not numerous, and exposure would be better to bear than if exposed on the Red Sea. In comparison with the journey by the steamer on the Red Sea, the railway would be easier, the current of air would be more refreshing; in the case of the former, the steamers are often forced to turn round so as to get air into the ship, to save the passengers from the intense heat. For the conveyance of the light, valuable goods, mails, passengers, troops, and treasure, the Euphrates route would be the best, and both lines would assist each other; there are people and commerce enough to occupy both. The distance would be, from London to Brindisi, 1,504 miles; from Brindisi to Selucia, or Scanderoon, 900 miles. The line of the Euphrates, along the river, as proposed for the railway, is 850 miles, that is from the sea to Bassorah; then, from Bassorah to Bombay, the distance is 1,690 miles. The total distance from London to Bombay is 4,944 miles. The route, *via* Brindisi, Suez, and Aden, the distance is 5,472 miles, from London to Bombay, and from London to Kurrachee it is 5,247 miles. The difference in favor of the Euphrates line is, from London to Bombay, 528 miles, and from London to Kurrachee, 803.

With respect to the arrangements that it would be necessary to enter into with the Turkish Government, and the means

by which the capital to complete the undertaking could be raised, we learn the full particulars in the evidence given by Sir George S. Jenkinson, Bart., a member of the Committee. From conversations and written communications with the Turkish Minister, his Excellency, it appears, on every occasion expressed himself personally most anxious on the subject, and that the completion of the project would be especially favored by the Sultan. The result of these interchanges of opinion was reduced to a written document.

The Turkish Government consents to the construction of the railway on its own account, from Alexandretta to Aleppo, and from Aleppo to Bagdad and Bassora, at the head of the Persian Gulf, under the direction and working control of a mixed committee, to be jointly appointed by the the English and Turkish Governments, and upon the following conditions :—1. The funds to be raised by means of an Ottoman loan, the interest of which to be counter-guaranteed by England, at the rate of 4 per cent. per annum, and one per cent. for sinking fund. 2. The proceeds of such loan, when raised, to be deposited in the Bank of England, in the names of the mixed committee, and to be applied by them exclusively for the construction of the railway, and the provision of the necessary rolling-stock, and for no other purpose. 3. All the land necessary for the railway, and for all the works in connection therewith, to be provided for by the Turkish Government. 4. In order to secure, with regularity and certainty, the payment of the interest upon the loan, the following stipulations to be agreed upon and enforced :—1st. The net income proceeds of the working of the railway when made, wholly or any part of it, to be paid into the Bank of England, and applied exclusively to the payment of the interest of the sinking fund. 2d. The customs duties and port charges of the ports of Alexandretta and Bassorah, as well as certain revenues and other resources of the province through which the railway may pass, to be assigned by the Turkish Government to the mixed committee, as a security for the payment of the interest of the loan and of the sinking fund. 5. The Turkish Government to guarantee to England the privilege of the conveyance of troops at all times by the railway to and from this country and any of Her Majesty's Eastern possessions, and at a rate not exceeding that which will be paid for a conveyance of troops belonging to the Ottoman Empire, and upon such other conditions and regulations as shall be settled and agreed upon by a convention between the English Government and the Sublime Porte. 6. The transport, free of any charge, at all times, by the railway, of all English mails to and from this country, and any of Her Majesty's Eastern provinces. 7. Until the extinction of the loan, by the repayment of the principal and interest, the English Government and the bond-holders, as represented by the committee, to have an absolute mortgage upon the railway, and land, and works.

GASES FROM THE BESSEMER CONVERTER.*

By MR. G. J. SNELUS, A. R. S. M.

This investigation was undertaken in the hope of solving some of the difficulties connected with the spectroscopic observation of the Bessemer flame, and also as likely to afford a further insight into the nature of the process going on in the converter.

The gas was collected for analysis by means of an iron gas pipe, having a swan-necked trumpet mouthpiece of fire-clay, which was dipped into the mouth of the vessel after it had been turned up. The gas from its pressure in the converter, rushed through the pipe with some velocity, and after the whole of the air had been swept out, glass tubes were attached, and when filled with gas, at particular periods of the blow, were hermetically sealed up with the blow-pipe before removal.

The gas was analyzed in some cases by two different methods, and the duplicate results were found to agree.

The following tabular statement shows the composition of the gas at different periods of a blow lasting 18 minutes:

* Abstract of a paper read before the Iron and Steel Institute, on the Composition of the Gases evolved from the Bessemer Converter during the Blow.

	No. 1 Taken 2. from start.	No. 2 4.	No. 3 6.	No. 4 10.	No. 5 12.	No. 6 14.
Carbonic acid	10.71	8.57	8.2	3.58	2.3	1.34
Carbonic oxide	None.	3.95	4 52	19.59	29.3	31.11
Oxygen	.92	....	Absent.	Absent.	None.	None.
Hydrogen	....	.88	2 00	2.00	2.16	2.00
Nitrogen	88.37	86.58	85.28	74.83	66 24	65.55
Hydrocarbons	....	....	....	....	None.	....
	100.00	100.00	100.00	100 00	100.00	100.00

On dissecting these results we find that the oxygen corresponding to the nitrogen in No. 1 is sufficient to oxidize not only the 4.43 parts by weight of carbon that are contained in the gas, but also 11.91 parts of silicon, and as these two bodies are practically the only ones being burnt from English Bessemer iron at this period of the blow, we may take it that these are actually the proportions in which carbon and silicon are now being got rid of from the metal. And this is exactly what analyses of the metal at this stage show, for it was found in one instance that metal containing 3.57 parts carbon and 2.26 silicon at the commencement, lost .53 parts of carbon against 1.305 parts of silicon in the first few minutes. Analyses of the gas from another blow about the same time, made by W. Thorp, F. C. S., of the Rivers' Commission Laboratory, show practically the same results. Sample 3 shows that 5.27 parts of carbon are being burnt along with 11.74 parts silicon. Sample 4 was taken after the commencement of the "boil" when the complete carbon specimen had become permanent. It shows quite a different result from the previous analysis, the large percentage of carbonic oxide now present explaining why the flame has become so much more luminous. We now find that 9.6 parts of carbon are being oxidized along with 6.25 parts of silicon. Sample 5 was tested specially for hydro-carbons; but none were found. Sample 6 shows that 13.45 parts of carbon are being burnt at this period and only .46 parts of silicon, which corresponds with analysis of the metal, these proving that the last traces of silicon go off very slowly.

The author considers that the reason why carbonic acid is formed during the first part of the blow, and carbonic oxide at a later stage is to be found in the increase of temperature during the blow. This agrees with experiments of Mr. Bell, who proved that at a low temperature carbonic acid was more stable than carbonic oxide in contact with iron, but that at a high temperature the reverse was the case. It also agrees with general observations. As a general result the comparison of the gas analyses with spectroscopic observations, shows that the reason why we get a continuous spectrum at the commencement of the blow is that we have then only white hot solid matter to look at, there being no actual flame, and the temperature being too low to give the specimen of carbonic acid, while later in the blow we have an abundance of carbonic oxide burning at the mouth of the vessel, which is also at a very high temperature, and, therefore, we get a carbon spectrum which is distinct from other carbon spectra yet seen, because we have not yet been able to examine the spectrum of carbonic oxide at the particular temperature of the Bessemer flame. Mr. Snelus believes that Deville's theory of the increased luminosity of flames under great pressure being due solely to the increase of temperature, is applicable to the great luminosity of the Bessemer flame compared with that of carbonic oxide burning at a low temperature. On comparing the gas from the Bessemer converter during the latter part of the blow with blast furnace gas, and with analyses of gas from Siemens' producers, given by the writer, it is seen that the former is as valuable a fuel as any of them, and as works using 1,000 tons of pig per week is sending this gas to waste at the rate of an equivalent of 25 tons of coke per week, its economical application becomes a point of great importance.

The writer believes this could be accomplished in a simple manner.

THE NORTH SEA CANAL.*

"A visit to the Suez Canal in my canoe (which was related in the "Times" a few years ago) enabled me to compare the North Sea Canal with that larger, more mundane, but not more remarkable example of human industry and patience, cutting the land in two to abridge the seas, levelling whole mountains of sand, battling with deep tides and hidden springs, stormy waves, and thousands of dubious or impatient shareholders—by far the most difficult obstacles for the venturous capitalist and the clever engineer.

"I have already explained that the North Holland Canal, which was cut to save a roundabout from Amsterdam by the Zuyder Zee, is more than 50 miles long, and enables large ships to enter Holland at its extreme northern end. But this canal is too long, too narrow, too tortuous, and too shallow for the increasing length and depth of our largest merchant vessels. To save time, then, and much trouble and transhipment, the new canal opens to the west instead of to the north. It is 15 miles in length instead of 52. Its depth is 26 ft. available instead of 16 ft., and no bends or sudden turns obstruct the passage anywhere. Six years ago this work was begun by the well-known English contractor, Mr. Lee. With Mr. Hawkshaw and Mr. Dircks to plan, and Mr. Freeman to execute, and a wealthy company to pay for it, all good folks ought to expect success.

"At present the work is precisely in that condition most interesting to inspect, being just beyond the state in which any doubt can remain as to ultimate success. Very likely this success will sap the other canal, and reduce Nieuwe Diep to a marine depot; perhaps it will also draw the golden tide from Rotterdam, but perhaps, too, the merchants there will shift their quarters to the better entrepot of Amsterdam, and yet perhaps, indeed, when all is done a certain German Prince will stretch out his iron hand and ask for the new road, and very graciously thank those who made it for him.

"First of all, locks are being placed on the east, to enclose an artificial lake about 12 miles long, at one end of which rests Amsterdam, and a deep channel is dredged along this lake, with two banks gradually rising into solid tow-paths. Minor canals, in all about 12 miles long, are left on either side to communicate with the little towns now on the shares of the Y, but all this intermediate area of water will be pumped out, and so nearly 12,000 acres will thus be reclaimed. No one can say how much this new territory will sell for, but an acre I asked about at random was valued at £100. The average may be ½ of this sum.

"The dredging is far better done than it was on the Suez Canal. The machinery has been steadily improved and simplified, and the latest and best appliance was only completed a few days ago. This consists of a tube resting near the ooze at the bottom, and containing a shaft with a centrifugal pump, which draws up the sand and water bodily—about half of each in the mixture—and forces it along wooden pipes floated on the surface of the water, and flexibly jointed by leather hides. The slush is thus poured through a conduit about 300 ft. long and 1 ft. broad, which resembles a huge black snake coiled and asleep on the water, and with its tail turned over the bank at the side. Through this tail, even when it is raised 8 ft. above the level, a copious fluid rushes, black as ink, but fertile for the next 100 generations of cheese-making Hollanders. So simple is this plan that already it is being applied to the great banks of the Danube, and I saw boxes full of the hide joints being sent to the Sulina mouth. Not many, but still some, curiosities have been found in the ground dug up or dredged for the canal. An enormous mammoth's skull and huge bones of the same fill one end of Mr. Freeman's office, and these ought to be in the British Museum, and could, I believe, be readily forwarded if properly applied for. One human skull has been dredged out 9 ft. below low-water mark, and I am enabled to bring it home. The size is large, the frontal part very small, the forehead being scarcely more than an inch in height. One or two pottery pieces have also been found, and, of course, plenty of shells. As no gravel has appeared in the matter dredged from below, it seems plain that the idea is erroneous which has long suggested that an ancient mouth of

* From Mr. Mc Gregor's letter, "London Times," through "Engineering."

the Rhine once led through Holland at this spot.

"The banks thus formed are gradually raised above the surface to the average of 3 ft., and then a layer of stiff clay is placed over the sand. On this is spread a sort of matting of loose reeds, which grow profusely in every lagoon. Long twigs of the willow-like tree, named 'rys,' are then laid down, and stakes about 4 ft. long are driven through them in rows, while a regular-twisted wattling of 'rys,' is securely worked into these, and the whole assumes a most business-like aspect, utterly different from the loose, unprotected sand-banks of the Suez Canal, which latter the water, the wind, and their own weight all conspire to ruin. Better than all the rest, a plant called 'helm,' which grows naturally on the sand-hills, is being planted like cabbage rows upon the new-formed banks, and this rapidly takes root, and binds all together.

"This plan is to be tried on the Suez Canal, but probably the climate and the larger proportion of salt water in the Egyptian sand may prevent the 'helm' from growing there. At the end of the lake we reach the 4 miles of solid sand and elevated ground which had to be cut through before the western shore of Holland is attained. The deepest cutting is not more than 100 ft., and is a mere matter of digging and carrying away. At length we come to the locks close to the sea. These are of enormous size, 500 ft. long and 60 ft. broad, with a depth over the sill of 30 ft. The stone-work facing of these is beautifully fitted, and the 25,000,000 of Dutch bricks here laid are a model of bricklaying. The width of the canal from centre to centre of the towing-path is about 500 ft., but at the edge of the main channel only 200 ft., and 80 ft. at the bottom; but this gives ample room for the largest vessels to pass each other. Now we are in the thick of the 'dunes' or sand-hills, Holland's western wall. They are not bare, but rather jungly in their look, and hares and rabbits, and curlew and spoonbills are plentifully found by the sportsmen on these wilds. Climbing this barrier we can look down on the two gigantic pier arms that stretch forth boldly into the stormy sea, and which keep steadily lengthening every week, and gradually bending in their ends to form the grand entrance to the new-born port. Nearly one-half of these piers is already finished, and this not by casting in the huge blocks promiscuously, as at Port Said, but by placing every one on its proper bed, well-fitted to its neighbors, and bound by iron-ties, so as to form a smooth-faced, upright sea-wall. The blocks thus placed are made of concrete and Portland cement, in weight about 10 tons each, just as at Port Said, and thousands of them are still on the shore waiting to be run along the pier, and then to be hoisted up by the iron neck of the great steam 'Titan' which will swing them into their final beds."

SOFT IRON AND STEEL CASTINGS.

From "The Iron Age."

The demand for some practical process which will furnish a reliable and inexpensive method of making malleable iron and steel castings, has attracted the attention of inventors to this line of production without, however, any great success hitherto. The latest process yet published is announced by the "Scientific American," and is the invention of Mr. Richard Yielding, of New York. The invention consists first, in making malleable iron or steel castings by casting the metal into hot moulds capable of inclosing it and protecting it from the atmosphere, and then allowing the moulds to cool gradually in a oven with a decreasing temperature. By this method the castings, it is claimed, will be annealed when cool, and the tedium and expense of making castings malleable is avoided, besides producing a softer and more homogeneous metal. A second process consists in lining the moulds with a decarbonizing substance, in order to more completely decarbonize the metal after being poured into the mould, and to enable it to remain sufficiently fluid to pour, thus making either soft castings of the nature of wrought iron, or steel castings, with less carbon than can be cast in the ordinary way.

The moulds used are made of plumbago

and fire-clay, ground carbon and like substances, capable of resisting great heat, and are raised to a white heat before being used, either in an oven or by other suitable means. The castings may be made directly in an oven, or the moulds placed in the oven after filling in such a manner as to protect the metal from the atmosphere and prevent possibility of chilling. The advantages claimed are the production of softer and more homogeneous castings, and that the iron does not shrink as ordinary castings do, but retains an elasticity due to the fine pores not being contracted, as they will be when subjected to chilling. This elasticity also prevents the metal cracking and breaking when subjected to blows and pressure. The decarbonizing linings are of such substance as bituminous coal treated with black oxide of manganese or chromate of iron to remove the sulphur, or coal and oxide of manganese may be used in combination, or the linings may be of magnetic iron and clay, charcoal or micaceous rock saturated in alum and water. The moulds thus lined are also to be heated to receive the molten steel, first decarbonized as much as can be in the refining furnace and remain fluid, which being cast, will be wholly decarbonized and produce very fine castings of the character of wrought iron, or the decarbonizing may be stopped at any point by the duration of time the moulds are allowed to remain heated, or the degree of heat to which they are subjected. Thus, it is claimed, carbon in the proper degree for either high or low grades of steel may be retained, or it may be entirely removed to make soft iron. The linings may be renewed from time to to time by washing the moulds with a solution of the decarbonizing substances in a pasty condition. The difficulty claimed in producing entirely decarbonized castings hitherto has been that the metal will not flow when decarbonized below two per cent. of carbon, while, by the above improvement, the inventor claims to have accomplished the desired result. Such is the process as described. In practice it would seem to have objections of expense in heating moulds, regulating temperature of oven and especially in preparing moulds.

Before the inventor can obtain the advantages justly to be derived from a thorough process of decarbonization, he must conduct this process in the molten metal, or during the process of melting. This is the desideratum to which the Bessemer process, the Danks mechanical puddler, and others, are directed, all moving in one direction—to eliminate carbon and avoid puddling as now conducted. A step further, or, rather backward, is, however, the true channel for inventors, in which to exercise their ingenuity. Why carbonize the metal in reduction to such an extent as to render all this subsequent decarbonizing labor necessary? In other words, reduce iron ore to the metallic state without the excess of carbon produced by the present process, and produce a malleable pig. Here is the grand objective point to be reached, and with the immense number of intelligent minds seeking it, it is not visionary to expect practical results in our day. The manufacture of steel becomes then perfectly simple, as the difficulty is not in recarbonizing, but in obtaining a homogeneous metal for the purpose.

The true route to malleable castings and cheap steel is through the blast furnace, and not in doctoring its product subsequently. The Bessemer product is not of a character to be classed as steel further than in its strength and hardness. It can not be tempered, and will not weld without great difficulty. This proves that the decarbonizing of an over carbonized metal, and the subsequent addition of the percentage of carbon named for steel, will not produce that metal. So of many of the other conversions before the market, scarcely one of them presents the real requisites of steel.

Thus, when we shall have produced a metal from the ore which shall be freed from the impurities of sulphur, phosphorus and silicon, and not contaminated with carbon, either graphitic or combined, we shall have reached the true malleable pig, and in the same process produce the steel pig by a simple change in manipulation of the burden in the furnace.

Meanwhile the foregoing processes offer many advantages for the production of small steel castings.

THERE are in America and Europe more than 250 manufactories of india-rubber articles, employing some 500 operatives each, and consuming more than 20,000,000 lbs. of gum per year.

RAILWAYS IN TURKEY.

From "The Engineer."

There is no longer any doubt that the railway system is going on in earnest in Turkey. The great Roumelian line is being prosecuted at several points. From Constantinople the short line which is opened is being continued towards Adrianople. The mistake has, however, been made of constructing first the branch line from Adrianople to the sea at Dede Agliaj, while the necessary port at this new point is not being made, so that it will do little good for the export of produce or the transmission of passengers. Undoubtedly, the whole resources should have been devoted to the prosecution of the main Roumelian line connecting Adrianople and Constantinople with the European system. The suspicion has naturally been excited that the Dede Agliaj line, being in easy country, has been pushed on to allow the contractors to draw a mileage rate. Beyond Adrianople the works of the main line are, however, going on to Filibeh or Philipopolis, a most important section. On all the works the engineers are chiefly Austrians, and among the sub-contractors are some English and French—a nice reversal of conditions, which is owing to the dissatisfaction caused by the proceedings of the English companies under Turkish auspices. In Constantinople most of the land and house property has been appropriated for the intramural line and great terminus, including 1,000 houses, and the works will be shortly proceeded with. It will have a wharf in deep water. The materials for the new floating bridge over the Horn, under French auspices, are on the spot. The only works partially under English auspices are a tramway on the Pera side to Bebek, now open, and a road to the upper Bosphorus. Constantinople has now become a centre of engineering activity, under the inspiration of the Sultan and the direction of an energetic Minister of Public Works, lately reappointed, Edhem Pasha. In mechanical engineering the English hold their own at Constantinople. Chiefs and workmen are actively engaged in the dockyard and arsenal, where large operations are carried out. The English workman has kept up the national character, which has not been so successfully maintained by the larger operators. The ports of Kustenji and Varna are not pushed with the requisite vigor and means. At Salonica extensive wharfage is being carried out in connection with town improvements and the removal of the old walls. On the Asiatic side Government is engaged in a new experiment, that of beginning the first section of the Asiatic railway in connection with the great Indo-European line through Constantinople. The Government, having been unfortunate in its concession of the Asiatic line, and being indisposed to engage at the other end in a Euphrates Valley line, which is of no immediate interest to them, particularly since the opening of the Suez Canal, are devoting some small means to the Scutari end. Military labor will be employed and every resource made available. The line has been objected to as being parallel with a steamboat route, but it is indispensable for the through line. This was a concession to Mr. James Landen, who spent a large sum on the surveys. The whole line to Bagdad is said to be embraced in the new financial combination called Lord Dalling's Company (Sir Henry Bulwer's). Meanwhile the works are being actively pushed on, and rails will soon be laid. By bringing Constantinople to bear on the interior districts, a real impulse will be given to the main line.

THE TEMPERATURE AND ELASTICITY OF STEAM.

By Mr. ALEXANDER MORTON.

From "The Artizan."

The early experimenters on steam, and other physicists since their time, have cherished the hope that some simple law would be found to connect the temperature, pressure, and density of steam, and as the subject had occupied much of the writer's time, he would now lay before them some results of his labors.

Until the publication of those beautifully accurate experiments of M. V. Regnault

on the temperature and elasticity of steam, we were without a chart to guide us. Those experiments were intrusted to him at the expense and by order of the French Government (published in the Memoires de l' Académie des Sciences," 1847), and are now well known to be the standard upon which mathematicians have labored to find some simple formulæ which would include their whole range.

When such physicists as Gay Lussac, M. Biot, and M. Regnault, including, also, some of our greatest mathematicians, have devoted so much of their time to this subject, its importance need not be questioned. From some experiments of the writer, and others which he had studied, he had been, so to speak, impelled to attempt this problem, and he had now adopted a formula and deduced his constants from M. Regnault's experiments, so satisfactory to himself, that he had prepared the annexed table to show the comparison between the formulæ and the "graphic curve" M. Regnault had given, and he hoped to be excused if, in pointing out the differences between his formulæ and those of others, he should inadvertently appear to undervalue their labors.

In calculating that table which M. Regnault has added as a summary of his experiments throughout their whole range, he found it necessary to make use of three distinct formulæ, neither of which could, with any degree of accuracy, be extended beyond the limits fixed by him. The first being from 32 deg. below Centrigrade zero to 0 deg,, or freezing point; the second from 0 deg. to 100 deg., or boiling point; and the third from 100 deg. to 230 deg. The third or last formula he terms "the unique formula" (H), and when compared with the "graphic curve" at the higher temperatures it is certainly very near; but at the freezing point and other low temperatures the difference of the logarithms is too great to warrant us in admitting such errors could have been overlooked by an experimenter of his experience and knowledge; hence the necessity for three distinct formulæ; moreover, these formulæ are not more simple than many which have been published since.

The most accurate formula, enclosing the whole range of the curve, was published fully 20 years ago in the "Edinburgh New Philosophical Journal" for July, 1849, and from that time to the present the writer was not aware of any since published that could at all compare with it, either for range or accuracy. This formula had been suggested to its author by our esteemed ex-president, Professor W. J. Macquorn Rankine, from his theoretical views on the action of heat; but that it is an absolute expression of the law, its deviation from the experiments at the lower temperatures leaves room for question.

Messrs. Fairbairn and Tate, in or about the year 1859, made a series of experiments with some very perfect experimental apparatus, with the view of determining the law of the density and expansion ofsteam,which formed the subject of a paper read at the British Association Meeting of that year; but these experiments having been subsequently extended and developed by these gentlemen, a full report was not made public until after the "Bakerian Lecture," May, 1862. In studying these experiments, and whilst comparing them with some he had made himself,with the view of defining the density of steam, the formula now under consideration, connecting the temperature and elasticity of steam, suggested itself to him, and to give them an idea of its accuracy he had prepared the large sheet now exhibited.

The first two columns give the temperatures in Cent. and Fahr. degrees, from—32 deg. to 230 deg. Cent. The third column gives the pressure in lbs. per sq. in. deduced from M. Regnault's "graphic curve" which is given by him in millimetres. The fourth column, also in lbs. per sq. in., has been calculated by the formula for the purpose of ready comparison. The fifth and sixth columns give the corresponding logarithms. He had added the last two columns in millimetres to show the differences more fully. Those pressures below the freezing point are copied from M. Regnault's summary table, and those above that point are copied from his table for the air thermometer, series H, page 608.

At—32 deg. Cent. the pressure 0.320 millimetres is the lowest experimental point upon which he founds his first formula; at that point the formula under consideration gives 0.319 millimetres, differing only the one-thousandth of a millimetre. At the freezing point the difference becomes about one-seventieth of a millimetre; at the boiling point about $\frac{1}{3}$

of a millimetre; and at 210 deg. Cent. or 410 deg. Fahr., the difference is only 6 millimetres in upwards of 14,000.

The intermediate stages are equally near, often nearer, and as the formula by logarithms becomes simple addition and subtraction, he trusted both formula and table might be found useful hereafter. One very important element in this formula is the first term of the denominator ($\sqrt{tt}$), which expresses that the square root of the temperature is multiplied by the temperature itself. The form of the expression as explained by Professor Rankine and others, is that which was adopted by Professor Ro he, and differs greatly from that adopted by M. Biot and M. Regnault. It is much more simple, and this fact commends itself. Of all the formulæ which have been from time to time proposed, he thought he had for the first time multiplied the square root of the temperature by the temperature itself, and he begged particular attention to that term. The zero points and constants which he had adopted were calculated to the best of his judgment from the standard experiments before named, and when the many corrections for different kinds of glass, pressure on the bulbs of the thermometers, etc., are taken into consideration, necessary in such delicate experiments, it is surprising how well they agree with the formula. For instance, at 250.0 deg.; Cent. by the standard air thermometer, Choisy le Roy crystal gave 253.00 deg; ordinary glass gave 250.05 deg.; green glass gave 251.85 deg.; and Swedish glass gave 251.44 deg. There is another point to which he would direct attention; in the experiments tabulated by M. Regnault, those performed with the air thermometer, and those with the mercurial thermometer, agree exactly with—32 deg. Cent. to the boiling point; but from that point upwards the pressure registered by the mercurial thermometer gradually declines until at the highest temperature, 230 deg. Cent., or 446 deg. Fahr., the pressure registered is 20160.0 millimetres, whilst the air thermometer for the same temperature registers 20915.0 millimetres. Now, near as his formula agrees with the air thermometer experiments, unlike all other formulæ heretofore proposed, at the highest experimental temperature it gives a less pressure than that by the air thermometer, and a greater pressure than that indicated by the mercurial thermometer; whereas all other formulæ at that temperature give a greater pressure than that indicated by either the air or mercurial thermometer, and this is a very important difference, more especially if the formulæ be applied to higher temperatures than those of experiment.

Near the beginning of this paper I stated that M. Regnault, before being able to construct his general table, had necessarily to make use of three different formulæ. The three points of the curve given by experiment he chose for a basis for his first formulæ were—32 deg.,—16 deg., and 0 deg. Cent. Thus:

Temperature. Centigrade	Experiments. Millimetres.	Formula. Millimetres.	Difference. Millimetres.
—32	0.320	0.319	— 0.001
—16	1 290	1.326	+ 0.036
0	4.600	4.586	— 0.014

For the second formula experimental constants chosen by him were thus:

Temperature Centigrade.	Experiments. Millimetres.	Formula. Millimetres.	Difference. Millimetres.
0	4.600	4.586	— 0.014
+ 25	23.550	23.695	+ 0.965
50	91.989	92.210	+ 0.230
75	288.500	288.391	— 0 109
100	760.000	759.620	— 0.380

His third, or, as he terms it, "the unique formula (H)," is given in his summary table before referred to. This formula embraces the greatest range of the "graphic curve," fixed by experiment, and at the higher temperatures is certainly very near it; but when used in calculating the lower temperatures; as he had already explained, its deviation from the experiments is too great to come within the limits of error. For instance, at the freezing point it gives 4.48 millimetres pressure. Professor Rankine's formula gives 4.47 millimetres, whereas, by experiment, the pressure is 4.600 millimetres.

$$\text{Log. } P = A - \frac{B}{\sqrt{tt - at^2}}$$

Value of the Constants.

$A = 6.0962000$

$B = 60962.00$ Log. $= 4.7850592.$

$a = 0.012884$ " $= 2.1100507.$

$t = 495.4°$ plus temperature in degs. Fahrenheit. or $527.4°$ below the freezing point.

Temperature and Pressure of Steam.

Comparison of M. V. Regnault's "Graphic Curve" with the Formula,

$$\text{Log. } P = A - \frac{B}{\sqrt{t} - a t^2}.$$

Temperature.		Pressure in Lbs. per Square Inch.		Logarithms of the Pressure in Lbs. per Square In.		Pressure in Millimetres.		
Cent.	Fahr.	Graphic curve	Formula.	Graphic curve	Formula.	Graphic curve	Formula.	
						m.m.	m.m	
—32	—25.6	0 00618	0.00616	$\bar{3}$.7915320	$\bar{3}$ 7898443	0.320	0.319	—
30	22	0.00746	0.00745	$\bar{3}$.8729693	$\bar{3}$ 8722283	0.386	0.385	—
25	13	0 01170	0.01179	$\bar{2}$ 0681376	$\bar{2}$.0717278	0.605	0.610	+
20	4	0 01792	0 01830	$\bar{2}$.2534617	$\bar{2}$ 2624613	0.927	0.946	+
15	+5	0.02707	0.02786	$\bar{2}$ 4325100	$\bar{2}$ 4449631	1.400	1.441	+
10	14	0.0405	0 0416	$\bar{2}$.6071512	$\bar{2}$.6197339	2.093	2.154	+
5	23	0.0602	0.0612	$\bar{2}$.7795611	$\bar{2}$ 7872300	3.113	3.168	+
0	32	0.0889	0.0887	$\bar{2}$.9491398	$\bar{2}$.9478656	4.600	4.586	—
+10	50	0.1771	0.1779	$\bar{1}$.2485775	$\bar{1}$.2501297	9.165	9.199	+
20	68	0.3663	0.3383	$\bar{1}$ 5266816	$\bar{1}$.5293209	17.39	17.49	+
30	86	0.6101	0.6135	$\bar{1}$.7858814	$\bar{1}$.7878696	31 55	31.73	+
40	104	1.0618	1.0664	0.0260334	0.0279153	54.91	55.15	+
50	122	1.7786	1 7830	0.2500754	0.2511622	91.98	92 21	+
60	140	2.8771	2 8797	0.4589557	0.4593577	148.79	148 92	+
70	158	4.5072	4 5067	0.6539056	0.6538550	233.09	233 06	—
80	176	6 8575	6 8534	0.8361697	0.8359048	354 61	354.42	—
90	194	10 1604	10.1532	1.0069134	1.0066047	525.45	525 08	—
100	212	14.6959	14.6884	1.1671956	1.1669739	760 00	759 62	—
110	230	20.7618	20.7879	1.3172650	1 3178109	1073 70	1075.15	+
120	248	28.7923	28 8330	1 4592767	1.4598900	1489.00	1491.10	+
130	266	39.2341	39 2626	1.5936640	1 5939794	2029.00	2030.47	+
140	284	52.4362	52.5628	1 7196318	1.7206788	2713.00	2718 29	+
150	302	69 0706	69 2705	1.8392935	1.8405186	3572 00	3582.33	+
160	320	89.8575	89.9697	1.9535547	1.9540962	4647 00	4652.69	+
170	338	115.2466	115.2882	2.0616283	2.0617852	5960.00	5962 15	+
180	356	145.8953	145.8927	2.1640412	2.1640333	7545 00	7544 86	—
190	374	182.3062	182 4842	2.2608016	2.2612254	9428.00	9437 20	+
200	392	225.4657	225.7875	2.3530806	2.3537000	11660 00	11676 64	+
210	410	276.6692	276.5535	2.4419609	2.4417790	14308.00	14302.00	—
220	428	336.2650	335.5470	2.5266816	2.5257533	17390.00	17352.87	—
230	446	404.4268	403.5310	2.6068399	2.6058768	20915.00	20868.67	—

Now, from what we know of M. Regnault as an experimenter, and consider the means at his command throughout the numerous experiments he has made at this temperature with mercury, and the different kinds of glass, whose corrections he must have known very exactly, it is next to impossible that he could have erred to the extent of 0.12 or about $\frac{1}{8}$th of a millimetre at the freezing point. At this point, above all others, every thing is in favor of correct indications, and that his best formula (H) gave so manifest an error at this point (and at lower temperatures gave still greater errors) is proved by his adopting special formulæ for different parts of the curve, and only using formula (H) for temperatures above the boiling point. In each formula above and below the freezing point M. Regnault takes 4.600 millimetres as his standard. He had therefore arranged his constants so that the pressure at this point becomes 4.586 millimetres, being only 0.014, or about $\frac{1}{10}$th of a millimetre less than that given by experiment, and he had done so because the pressure at—10 deg. Cent. below, and+10 deg. Cent. above that point is greater by the formula than that by experiment; but at these points, and (with the exception of the boiling point) all othe points where the indications of the thermometer are absolutely necessary, the chances of error, he considered, become increased.

In concluding, the author would have it understood that he did not say this equation was an absolute expression of the law; but being a simple formula, embracing the whole range of the "graphic curve," and coming so very near it, from the lowest to the highest temperatures, he thought the absolute expression might be questioned, and probably a step made in the right direction.

He annexed the values of the constants, and in converting pounds per sq. in. into millimetres, he used the logarithm 1.71361-80. For inches of mercury, 0.3087835. Specific gravity of mercury at the freezing point at Paris, 13.29593.

INDIAN ENGINEERING AND INDIAN RIVERS.

From "Engineering."

One of the greatest difficulties that has beset our engineers in India has ever been the uncertainty of the rivers. Sometimes this uncertainty has been with reference to the river channel which, in certain cases, is liable to change its course from time to time, and instances have been known of a bridge which once spanned a river bed, being left high and dry, whilst the river, divesting itself of the encumbrance, ran freely past it on one side. But a more serious, and also a more common danger to engineers and their works is the occasional occurrence of exceptional floods of irresistible force—which, finding too little waterway allowed for their swollen torrents, breach embankments, and carry away bridges as though they had been things of straw. For such events the engineer is not always to blame. There are, in most cases, no records in existence relative to the height of floods in certain rivers extending back to any great distance, and in such instances it is the usual custom to make inquiries of "the oldest inhabitant" living in the neighborhood of a proposed bridge, as to the level of the highest known flood, which is generally remembered by the fact that on one occasion the water reached the door sill of a certain hut, or extended to such a distance beyond a certain landmark; but beyond such questionable authorities there is little left to guide him in this most important investigation, and he has accordingly to make the best of such "proofs," and to make such provision for waterway as may seem necessary to meet the requirements of probable extreme floods of the future. After the construction of such works, however, improvements in the upper beds of a channel, and the removal of obstructions, may cause such increased facilities for the flow of floods as seriously to compromise any works lower down stream, and even the clearance of forest may, by removing one of the barriers imposed by Nature for preventing the too rapid flow of excessive rainfall on the catchment basin of a stream, into the natural drainage channel, cause such a disturbance of the relative proportions of river-bed to the drainage area, as to stultify all previous calculations relative

to the flow of water which it may be called upon to accommodate. Owing to the so-called "unprecedented" rains of this year in the Punjab, most disastrous effects have been produced upon some of the works on the Punjab and Delhi Railway, and as this is a subject which, above all others, perhaps, is most important to be considered in the construction of river works in India, we have thought it desirable to draw prominent attention to it on the present occasion, and, in doing so, it is not with any desire to reflect upon the want of forethought on the part of the engineers of that railway, but rather to draw special attention to a fact which, though now well known, is perhaps not sufficiently thought of and allowed for in the construction of those works, which must ever prove the weakest points of a railway, especially in India, namely, the bridging of rivers.

From Delhi to Moultan the railway passes over a country almost perfectly level, the exceptions being an almost imperceptible rise in the ground between the rivers, and the low broad beds of the rivers themselves. Between Delhi and Lahore the line crosses three great rivers, the Jumna, the Sutledge, and the Beas, besides a great number of smaller rivers, such as the Gugger, the Tengri, the Kalee Nuddee, and several large canals. Over the level country the railway is carried on a raised embankment, here and there pierced with culverts to give waterway to the periodical floods, and this embankment runs directly across the natural runs of the drainage. The embankment thus acts as a great dam, and when rain falls in too great quantities to admit of being carried off by the river beds, or the culverts, the country becomes flooded, and the surplus water is heaped up on one side of the dam, which must inevitably give way if it be not strong enough to resist the enormous weight, or become breached should the water at any one point overtop the summit of the embankment, or the culverts may be blown up by the force of the water, resulting in either case in the destruction of a portion of the railway. The flooding of a considerable tract of country may also, besides the destructive consequences above named, be followed by evils not less to be dreaded, upon the subsidence of the waters, namely, such as arise from malarious exhalations. And it is not altogether unreasonable to suppose that the complaints on these grounds, raised by the natives in Lower Bengal some time back, may have had good foundation. They pointed out the injurious effects caused to the surrounding country, from a sanitary point of view, by the embankments of the East Indian Railway, which, they asserted, by interfering with the proper drainage of the country, caused an increase of swamps and their usual malarious effects. Across the rivers the Punjab Railway is carried by means of girder bridges built upon piers, the piers being sunk on single wells. The Punjab rivers are noted for the shifting character of their course, and sometimes, without any apparent reason, a river will suddenly begin to bear against some particular point, and in the course of one season change its bed to the distance of perhaps several miles. Bridging these shifting rivers, therefore, is a difficult task, involving also, as it does, the responsibility of selecting some spot where, from local circumstances, such a deviation of channel is not possible to occur. Such immense bridges as those over the Sutledge and Beas may fairly be considered as great engineering triumphs, having been constructed in spite of great natural difficulties, one of the chief of which was the obtaining of a sold foundation for the piers; for on sinking to a certain depth in the river bed, quicksands of a peculiarly shifting nature were invariably encountered. Indeed, it is stated in a recent local report, that underneath the bed of every Punjab river there is an underground river of water and sand corresponding to the course of the external river.

The foregoing particulars and considerations will, in some measure, assist in accounting for the serious failures which have recently taken place on this railway upon the occurrence of an unusually high flood. The disaster itself, also, will not be an unmixed evil; for failures of great engineering works, not arising from the use of inferior materials in construction, or from recognized errors in design, are often the dearly bought experience which ultimately leads to improved knowledge; and although such a method of obtaining knowledge is to be deprecated, it is nevertheless through accidents and fortuitous circumstances that many great discoveries

and inventions have been made. Instead, therefore, of merely lamenting over a serious accident, or endeavoring to discover who shall be hung, the searcher after knowledge and truth will always endeavor to turn the occurrence to his advantage, and by making a faithful examination into the cause, learn how to avoid similar catastrophes for the future. Let us hope that the present lesson will not be altogether lost on the railway engineers in India, and that the numerous State lines, which have been so long talked about, if ever they are really commenced, and actually prosecuted to completion, may be found provided with every safeguard against accidents from floods, and other natural causes, which the experience of the past has proved to fall, as a rule, to the common lot of such works in India. To return to the recent accident on the Punjab and Delhi line. From accounts from India it would appear that the floods of the past season have not only damaged the embankments of this line, but the bridges have also suffered to such an extent that the traffic is virtually stopped, and it remains yet to ascertain the length of time and amount of expenditure that will be required to be expended before the line can be put again into proper working order. Amongst other calamities, the Beas bridge is broken. One pier has sunk, carrying with it the girders on each side. The defence wall, built to protect the junction of the bridge with the ordinary embankment, has been broken down, and a huge gap made in the embankment, through which the river is now rushing, as if in a new channel, over the engine which lately sunk into the gap. This, it is supposed, was caused by one of those circumstances referred to above, as being common to some of the Punjab rivers; and the river Beas, in seeking a new course towards the east, and so unduly pressing against that side abutment, caused the accident which we have now to record. The pressure in that direction appears also not to have slackened since the occurrence of the mishap, and now the embankment has been so damaged between the bank of the river and the Kurtarpore station, nine miles off, that traffic has been stopped. Between Kurtarpore and Phillour, on the banks of the Sutledge, the pressure of water has not been so great upon the embankment, but the bridge across the Sutledge is considered doubtful, and no trains are permitted at present to run over it. The eastern side of the Sutledge has been damaged, and the embankment is said to show signs of giving way. At Rajpoora the embankment has received some damage, and the bridge over the Gugger is broken. The rail is carried over this river by a girder bridge on piers, like the other great bridges. One of the piers has given way, and falling on the down stream direction, carried with it the span girders on each side. There had been exceedingly heavy rain during the night, causing the Gugger to rise 16 in., the force of which proved more than the bridge was able to withstand. Between Umballah and Sirsawa, the embankment is much damaged, and it is reported that one or two bridges over the smaller rivers have either given way, or are showing signs of weakness.

Such is the list of disasters caused to a single line of railway by a single flood, so far as the record of them has at present reached us. Of course there will be the usual commission appointed to examine into the cause of this calamity, and we shall look forward with considerable interest to the appearance of their report, which, it is to be hoped, will not be confined to a mere narration of the fact that an unusually high flood caused an unusual amount of damage to the railway, for which no one can be held responsible; but that some useful deductions may be drawn from the circumstances of the case, which may prove instructive to engineers generally, and especially to those who may be engaged upon the preparation of designs for future railways, or for the execution of such works as will be required for the repair of the line in question.

THE "Shipping and Mercantile Gazette" mentions that the recent struggle between the Great Northern and Midland Railways regarding the coal traffic has led to a movement in the north to revive the sea-borne coal trade, by means of screw colliers of a greatly increased size, and on a new principle, by which it is believed supplies may be sent to London at some shillings per ton below the price at which they can be delivered by any railway lines.

MAXIMUM VELOCITY OF METEORIC STONES REACHING THE SURFACE OF THE EARTH.

From "Nature."

In Prof. Nordenskjold's account of the Aerolitic Shower which took place near Hessle, in Sweden, on the 1st of January, 1869, he mentions as a remarkable fact, that stones weighing 2 lbs., which struck the ice of the Larsta-Viken, failed to penetrate, making holes only 3 or 4 in. deep in the ice and rebounding. (Vide the "Academy," Dec. 15, 1870.)

The small velocity retained by these stones, at the time of striking the earth is, doubtless, owing to the resistance of the air, and, consequently, is not an indication of the velocity which they had upon entering the atmosphere.

Stones thus penetrating the atmosphere from interplanetary space, would be moving in a resisting medium under the joint influence of their original velocity of translation and the constant action of terrestrial gravity. In the case of small masses, the resistance of the medium would very speedily produce retarded motion; and before traversing 20 or 30 miles of air, they would probably move with a velocity approximating uniformity, and under the action of gravity alone. In other words, they would gradually lose their original velocity of translation, and, descending, nearly or quite vertically, under the action of gravity, would ultimately attain a maximum velocity under the opposing influences of the resisting and accelerating forces, and then descend to the earth with this uniform velocity.

Thus, for example, a rifle bullet shot obliquely into deep water, would very soon lose the horizontal component of its velocity, while the vertical motion would be so rapidly retarded that, at a comparatively short distance below the surface of the water, it would begin to descend vertically with the very moderate uniform motion resulting from the resistance of the liquid and the constant action of gravity.

In like manner, no matter how great the velocity with which a meteoric stone enters the atmosphere, the enormous resistance which it encounters must operate ultimately to produce a similar result, although, in some cases of oblique incidence, the horizontal component of velocity is not entirely lost before reaching the earth.

It is well-known that this maximum or limiting velocity of a falling body is attained when the required velocity is such that the resistance is at each instant equal to the weight of the moving body. In the case of small masses moving in the air, it may be shown that this velocity is quite moderate.

The principles of dynamics furnish the means of determining the resistance of a given body moving in a medium of a given density when the size of the body and its velocity are known.

Let A = area of cross-section of body at right angles to direction of motion.
D = weight of unit volume of medium (air).
v = velocity of moving body (meteoric stone).
g = acceleration by gravity in a unit of time.
k = a constant co-efficient, deduced from experiment, depending upon the shape of the moving body.

Then we have,

$$\text{Resistance} = k \times A \times D \times \frac{v^2}{2g}.$$

Hence, by the conditions under which, as above given, v becomes a maximum, if w = weight of moving body or stone, we have,

$$k \times A \times D \times \frac{v^2}{2g} = w \therefore v = \sqrt{\frac{2g \times w}{k \times A \times D}} \quad (a.)$$

Applying this formula (a) to the case of a meteoric stone weighing 2 lbs., moving in the air:—let us assume it to be a cubical mass, having a specific gravity of 3 in relation to water as unity. Then its volume = 18.482 cub. in., and the area of one of its faces = 6.9903 sq. in. = 0.048544 sq. ft. Hence, assuming the resistance to act at right angles to the face of the cube, and taking the pound and foot as units, we have

A = 0.048544 sq. ft.
D = 0.0807288 pounds = weight of cubic foot of air at 0° C.
w = 2 lbs. weight of stone.
g = 32.1928 ft. per sec.
v = required maximum velocity in feet per second.

Hence, by formula (a).

$$v = \sqrt{\frac{2 \times 32.1928 \times 2}{k \times 0.048544 \times 0.0807288}} \sqrt{\frac{128.77}{k \times 0.0039189}}$$

$$= \sqrt{\frac{32859}{k}}.$$

Or, $v = \frac{181\ 27}{\sqrt{k}}$ in feet per second.

Assuming $k = 1.3$,* we obtain,

$v = 158.99$ (= 159) ft. per second, as a maximum velocity attained by such a stone in falling to the earth. This velocity does not exceed one-tenth of the initial velocity of a rifle bullet. And, as the penetrating power of a given projectile is proportional to the square of its velocity, its power of penetrating the ice would only be one-hundredth part as great as that of a projectile of similar mass and dimensions moving at the rate of a rifle bullet. Hence we need not be surprised that the ice was not penetrated more than 3 or 4 inches.

If the same mass of stone (2 lbs.) were spherical in form instead of cubical, its diameter would be 3.2803 in. = 0.27336 ft., and A =0.058689 sq. ft. In this case, we may assume $k = 0.7$.† Hence. by the formula (*a*) we obtain,

$v = 197.05$ ft. per second: so that in this case likewise its velocity would be quite low, and its penetrating power very insignificant.

Of course, in the case of large meteoric stones the value of v would be greater.

* For cubes moving in water the experiments of Du Buat and Duchemin give $k = 1.280$.

† For spheres moving in air the experiments of Robbins and Hutton give for velocities:

$v = 3.28, 16.4, 82, 328$ ft. per sec.

$k = 0.59, 0.64, 0.67, 0.71$.

THE BROAD AND NARROW GAUGE FOR RAILWAYS.

The assertion has been so often made that a broad gauge railroad, although possessing points of superiority over the narrow gauge, is on the whole inferior, and costs very much more than a narrow gauge road, that a correct statement of the case is demanded for the information of the public.

By the broad gauge road, is supposed a road like the Erie (late the New York & Erie), the track of which is 6 ft. wide; that is, it is 6 ft. in the clear between the two rails of the track; and by the narrow gauge a road having a width of track of 4 ft. 8½ in., or 4 7-10ths ft. in the clear between the rails. In England, the term "broad gauge" means a gauge or width of 7 ft. No such gauge has been adopted or recommended for any railroad in the United States. More recently a narrower track than 4 7-10ths ft., that is, a track 3 to 3½ ft., has been advocated as suitable for railways in certain localities. These, it is probable, will not assume importance enough to be considered in a general scheme for railway transit, and hence will not be discussed in this investigation.

The rails of a railway designed for general traffic and travel, and for the use of locomotive steam power, are formed usually of iron. They weigh from 56 lbs. to 80 lbs. per lineal yard, and are connected by joints of the same material. The rails are spiked or fastened by their lower web to cross sleepers of wood, which serve as supports, and as ties to keep the rails at a uniform and proper distance apart.

To arrive at the correct relative cost of a 4 7-10ths ft. and 6 ft. gauge, the same plan of construction should be assumed for both, and the items in each considered separately, and their value carefully estimated.

The comparison should be made free from prejudice, and free also from any interest, direct or indirect, in the numerous establishments for engine and car building in the country.

If timber ties or sleepers of the same number and quality are used for both gauges, those of the broad gauge will cost the most because of their greater length. The two gauges differ in width 1 3-10ths ft.

Ties for the narrow track are are usually made 8 ft. in length. For the broad track they should, therefore, be at least 8+1 3-10ths or 9 3-10ths ft. or about 1-6th longer. This additional length will cost, probably, about 1-5th more.

If, therefore, narrow gauge ties can be obtained, delivered on the line of the road where used, for 50 cents each, which is, probably, above their average cost, the broad gauge ties should cost 60 cents each; and if the usual number of 2,340 per mile are used in both cases, the additional cost per mile of the timber ties on the broad gauge will be 2340×10 or $234. The ballast will also cost more, and about in

the same proportion as the ties, or about $180 per mile more, making a difference in both items of 234+180 or $414 per mile in favor of the narrow gauge in the cost of superstructure for a single track, the labor of putting the rails in place being supposed the same in both cases.

There is also a difference in the same direction in the cost of the equipment, or the rolling stock, in the greater length of the four axles and greater width of the truck frames of each car, equal to about $60 to each eight-wheel car, and $140 to each locomotive and tender. This assumes that outside bearings are adopted on the broad gauge, which is not customary; with inside bearings the cost of the cars is not increased.

A railway when properly equipped for doing a very good business requires 1 locomotive for each 3 miles of road, and 6 eight-wheel freight and passenger cars, and 1 four-wheel gravel car for each mile of road, making the extra cost per mile for equipment on the broad gauge about $440 per mile with outside bearings, and not over $50 per mile with inside bearings. This increased cost is more than counterbalanced by the less weight needed for the rails and the wheels on the broad gauge to render them equally serviceable and strong with those of the narrow one.

This less weight is determined by the greater strain to which the rails and the wheels of the narrow gauge are subjected when the rails are not properly adjusted, as is frequently the case, a strain at times much increased by the lateral force of the wind.

The entire force thus acting to injure or fracture a rail or wheel by the lurching caused by a depression of a given depth in either rail, is full 15 per cent. the greatest on the narrow gauge. Assuming one-tenth to be saved in the weight of the wheels and rails, which is a moderate estimate, and estimating 5 cents per lb. for the former and $90 per ton for the latter, the saving amounts to $1,000 per mile for a single track, and twice that for a double one; an amount which exceeds the cost of the items for longer ties, ballasting, etc., as above stated, for the broad gauge. Keeping in mind, therefore, that the question of gauge is alone being considered, and that the equipment is to be no heavier on the broad than on the narrow gauge, it will be found on a fair estimate of the relief afforded to the wheels and rails, and other advantages by using the broad gauge, that the whole will exceed the sum total of the items in which the broad exceeds the narrow gauge in first cost.

It is not easy to arrive at the precise difference of the two in figures. Of the other advantages, it is easy to understand that the broad gauge, because of its wider base, gives a more steady movement to the train, and there will be less of that irregular sideway or lurching movement which tends to strain and wrench and weaken the bodies and frames of the cars, and the machinery of the engines, and which is a principal cause of the depreciation of the rolling stock on all of our railroads. There can be no doubt that a steadier and more equable movement of the trains will result in less injury to the road and its equipments, less cost of repairs, and more effect to the motive power.

To assume that the cars and engines, because of this less wear and tear, will last one year in twenty longer, is believed to be a moderate estimate; and one-twentieth part of the cost of equipment per mile average, is about $1,000. To this should be added another large item that cannot easily be estimated, in the increased revenue from its superiority over competing lines on the narrow gauge, by giving increased comfort and safety to travellers. There are some other items of cost in making the comparison, which it is proper to consider. A writer in a prominent New York daily, the "N. Y. Tribune," not very long since made this declaration that, "on a broad gauge road it is clear enough that in the first place, the original outlay in the cost of the road is much greater than on a narrow gauge road." That, "at the outset the right of way costs more, and the road bed costs more, the bridges cost more, everything, in short, costs more."

Such assertions are not sustained by the facts or by sound argument, and are positively injurious and criminally so, as their tendency is to mislead on a subject of the greatest importance to the public and the owners of our railways. As to the right of way costing more, the absurdity of the assumption is obvious when it is considered that the narrowest of the narrow gauge cars is more than 3 ft. wider than

the broad gauge track. Hence, wherever a narrow gauge car can run there is abundance of room, or right of way, for laying a broad track, and no additional right of way is required. As to the road-bed, 15 ft. is the customary width of the road-bed for a single track on the narrow gauge, but even if it be from 2 to 4 or 5 ft. less, giving a width of only 10 ft., as is sometimes the case on second and third class roads, it still can support a 6-ft. or broad gauge track. The track being double does not alter the case. The space between the tracks is governed by the width of the cars, which is assumed the same for both gauges. The width of road-bed regulates, of course, the length of the culverts, the amount of masonry in them, and their cost.

The cost of a culvert of masonry is made up in a large measure in the cost of the end and wing walls, which is the same on either gauge for the same opening or water-way. To lengthen the body of a culvert of medium size, say 4 ft. chord, to the extent of 1 3-10ths ft. (the difference in the width of the gauges), will require not more than 2 cubic yards of masonry, which with the foundation will not ordinarily cost over $30 or $40. It is obvious, therefore, that the cost of the road-bed is not greatly or materially increased to adapt it to a broad gauge track.

As to the bridges, there is no difficulty in laying a track 6 ft. wide on a bridge designed to pass narrow gauge cars. The latter are never less than 8 ft. wide and passenger cars are oftener 9 to 11 ft. The bridges, therefore, not being wider, are not more costly on the broad gauge, but, on the contrary, there is some saving in cost, for the rails of the track being nearer to the vertical truss frames, the transverse beams on which they rest may be smaller, and of course lighter, and less expensive. An useless weight is thus taken from the bridge, and it is stronger for the support of the trains passing over it. Other items are not increased, such as excavation in tunnels, drainage in excavations, snow guards, and fencing, warehouses and depot buildings, labor expenses of operating the road, and fuel, the general expenses which form a large item, including salaries, office rent, etc., and what is usually also a very considerable item in the cost of roads, the interest account. All these are not increased.

It is evident, therefore, that the writer referred to is altogether wrong in his statements, and that the assertion that everything necessarily costs more on a railway having a broad gauge, has no foundation of truth to stand upon; but, if properly built, the broad gauge road will not differ greatly in cost from a narrow gauge road on the same ground, and that difference, even if in favor of the narrow gauge, which is not probable, is more than made up by the broad gauge being less expensive to operate and maintain, the wear and tear upon it being less.

A little reflection will also show that, *all other things being equal*, there must be greater security and safety, as stated, upon railways having the broad gauge, and consequently fewer broken limbs and fewer lives sacrificed, and a less amount of damage for items of this character.

As to the greater safety, it should be understood that the great injury to and wear of the rails of a railway is produced mainly by the driving or drawing wheels of the engines, which, to obtain adhesion, are loaded often with a weight of 5 to 7 tons on each wheel, a weight so great that there is very little or no *give* to the springs; and hence, if the track is at all out of adjustment, as railway tracks too often are, the wheels of the engine, in passing a depression in the rails, strike into it with a sledge-hammer force, increased in intensity just in proportion as the track is narrower, since upon such a track the sidewise or lurching action of the engine is greatest. This is a result which no well-informed mechanic will or can question, and the extra annual injury and wear to the rails and machinery on the narrow gauge from this cause alone on a road doing any considerable business, is very much greater than the interest on the particular items wherein it has been shown the broad exceeds the narrow gauge in first cost.

This is no exaggeration. The rails of the narrow gauge suffer most, and the danger is greatest of the breakage of both wheels and rails, other things being equal, as stated.

Upon the narrow gauge roads, to satisfy the requirements of the public for more comfort, and accommodation, and speed, passenger and dormitory cars are expanded to an inordinate breadth and height, as compared with the gauge, and hence

are increased in weight, and made top-heavy, because of their narrow base. The increase in speed demanded by the public is only effected by increasing the dimensions of the boilers of the engines, which, to get heating surface, are made so broad as to require to be placed above the drawing wheels, thus increasing the relative height of the centre of gravity of the mass of the engine, and increasing, also, the strain upon the rails and wheels, and the wear and tear of both, and of the machinery on the narrow gauge.

These are great evils, and increasing. *Nearly all of our narrow gauge railways are burdened with an equipment better suited to a broad gauge,* but not necessary to it. This disproportion of equipment to gauge causes an amount of injury and damage to the roads and machinery, and a greater liability to accidents, which is not fully understood by railway stockholders and the public. The life of the rails is thus, beyond doubt, greatly shortened, and the fact has not come home to the consciousness of those managing the roads, as it will come in a few short years, when the great wear and tear of the roads will be made obvious in the cost of renewals and repairs. A limited period may show no very marked difference in the wear in the two cases; but when such is the case, it is safe to assert that the attending circumstances are not equal, or otherwise it must be assumed that the laws of nature are capricious, which no sane person will dare to affirm.

There is still another consideration of importance, which should not be overlooked. When railways enter cities, as they must, changes in their direction are often so sudden, in following the streets, that the wheels upon the outer rail of a curve must bear upon their flanges, instead of their rims. To turn a given curve in this manner, the flange may be deeper upon the wheels of the broad gauge cars, and this greater depth to the flange adds to the safety of the broad gauge cars upon those portions of the road where steam is used as the moving power. There is no limit to the use of a broad gauge in a city, which does not apply to a narrow gauge as well, for the broad track of 6 ft. can be laid wherever narrow gauge cars can run, as it is narrower than the narrowest car.

The necessity, moreover, of running the cars of a train into the streets of a city, makes it also necessary to give to the city horse railroads the same width of track as other railways. Now, $4\frac{7}{10}$ ft. is too narrow a space for two horses to work in comfortably, abreast; and the inconvenience of tandem teams, as used in Baltimore and other places, in our densely populated cities, is too great to be generally allowed.

The injury to horses or mules working abreast between the rails of a narrow track is very great; one or the other is being constantly crowded on to one of the rails, which would not be the case if the gauge was 6 ft. The injury to the feet and limbs of horses from this cause alone, cannot be easily computed. It is thought to amount in New York city annually to several thousands of dollars.

It may be urged that the resistance upon the curves of the road is greater upon the broad gauge. This is true; but the difference is too small to be appreciable in the cost of operating the road. If the curved portions of a railway are assumed to average ordinarily 24 deg. of deflection to the mile (a large allowance for roads west of the Alleghanies), the difference in length of the two rails of a track on the broad gauge, for the 24 deg., is 30 in.; and on the narrow gauge it is 24 in. The difference is 6 in., which is the additional sliding for the 24 deg. on one rail of the broad gauge. A like change in direction for each mile for every 100 miles, makes the total sliding (not allowing any relief from the slightly conical form of the rims of the wheels) 50 ft. for one side or one half of the train, and only 25 ft. for the entire train, which, as an item of resistance, is less than the power usually lost by the application of the brakes in arresting the motion of a train at a single station. It is obvious from this that the increased resistance and wear of rails from curves on the broad, as compared with the narrow gauge, is too small to be seriously considered in determining the merits of the two, and will be less than it now is when steel rails are used.

The curvature upon a railway because of the straightforward tendency of bodies in motion, a tendency which is increased as the speed of the train is increased, (the wheels of a railway car being firmly fixed to the axles), adds to the danger of

the engine leaving the track. The oblique manner in which the moving power acts, also, adds to the resistance, and the two constitute the total resistance nearly, and great objection to curves upon a railway. This danger and resistance is not increased by any difference in the width of the track when the curvature is the same, but at any given rate of speed the danger is really somewhat less on the broad gauge, and for the following reasons:—

1. The centre of gravity of the engine, and the cars and their loads, is relatively lower; and

2. And the flange of the wheels is deeper.

The only proper and correct mode of comparing the two gauges, is to assume, as has been done thus far, that the equipment is the same for both. There should be no difference in this respect, except what is absolutely demanded by the difference in the width of the tracks. This view, while it is necessary to a clear and just comparison of the merits of the two gauges, is not sufficiently comprehensive to embrace all of the advantages of the broad gauge, which are greater than has yet been stated. Such a gauge enables a railway company to do, *if the convenience of the public, or their own interest, requires it, what cannot be done on the narrow gauge.* The greater width or space between the wheels of the engines permits the use of boilers of larger diameter, having more heating surface, and capable of producing more steam in a given time, giving greater power and ability to attain a higher speed. The diameters of the boilers being as the gauge of the tracks, if their length is the same their heating surface will be as the square of their diameters, or as $(4.7)^2$ to $(6)^2$, or as 22 to 36 nearly, or full *sixty* per cent. the most on the broad gauge, and the power and speed of the engine may be increased accordingly.

The broad gauge does not compel the use of more powerful engines, but if such engines are needed, they can be employed, and with less wear and injury to the roads, and danger of accidents, than on the narrow gauge. If broader and higher freight and passenger cars are needed for the greater convenience and storage of freight and accommodation of passengers, they can be had on the broad gauge; but the gauge does not require that the cars should be either broader or higher. It is optional with the companies to make them so or not, and here it should be noticed, that by adding to the width of a freight car, its capacity for holding freight is increased in a somewhat greater ratio than the weight of the car or its cost. This is a gain of some importance to be credited to the broad gauge, particularly in the transport of bulky articles, such as hay, cotton, furniture, etc.

Again, if more space, and comfort, and accommodation are needed in the passenger and sleeping or drawing-room cars, they can be had to a much greater degree on the broad than upon the narrow gauge. These latter advantages, it will be seen, demand an increase in the cost. They are not essential to the broad gauge, only incidental to it, and no railway company would incur the additional cost, unless to promote its interest. They are improvements or changes which the wide gauge enables a company to make; if demanded by the public, and its own interest, and which cannot be so easily attained, or attained at all, on the narrow gauge.

In whatever light the subject is viewed, there is no escaping the conclusion of the superiority of the 6 ft. over the narrow gauge of 4 7-10 ft. for our main lines of railway.

The consideration of most weight which can be urged against the broad gauge is the inconvenience and expense of making connections with other railroads.

If such connection is demanded under circumstances which render a transfer of freight from one road to another too expensive, the difficulty may be obviated by putting down a third rail on the shorter of the connecting roads.

This third rail, if added to the wide track, involves no expense but the cost of the rail and fixtures and laying down.

If added to the narrow, the ties must be lengthened. Its cost will be so much additional capital without loss otherwise, as the wear upon two of the rails will be no greater than the entire wear upon the third, and the two rails will last twice as long as the third one; and the profits of the road will not be appreciably lessened in the long run, while the road itself, by means of the third rail, will have more solidity and will be less liable to be dis-

turbed by the movement of the trains over it, and maintain its adjustment better. The third rail may, moreover, prove a security or guard to a certain extent in preventing trains, when off the track, leaving the road-bed, and may be worth for this purpose as much nearly as a track with 3 rails *ultimately* costs over one with 2 rails.

It will be seen from the above that a company owning a long line of road on the broad gauge, and having occasion to make connections with other roads of the narrow gauge, can commit no greater mistake than to alter to a narrow one.

The first railway built with a 6 ft. gauge was the New York and Erie, now the Erie Railway, and that road and many of its branch connections have still that gauge. Over 30 years have elapsed since the Erie road was commenced, and only about 15 or 20 years since it was completed. The Liverpool & Manchester, or gauge of 4 7-10 ft., had then been adopted in New England and upon some other roads. The Mohawk & Hudson was then commenced with $4\frac{3}{4}$ ft. gauge. The Charleston and Augusta, Georgia, with a gauge of 5 ft. The line from New Orleans north with a gauge of $5\frac{1}{2}$ ft., and in New Jersey $4\frac{83}{100}$ ft. was adopted, and the same in Ohio, although one road in Ohio had a gauge of 5 ft., and not very long after the Canada gauge was fixed at $5\frac{1}{2}$ ft., which was the gauge subsequently adopted in Missouri. These roads had all their beginnings at points remote from each other, and it was not until the railway system had become greatly extended, and the different gauges were brought in connection, that the companies began fully to see and to realize the very great error which had been committed in not investigating thoroughly the subject of the gauge for the railways, and fixing at the earliest date upon a proper and uniform gauge for all the railroads of the country. The attention of the Erie Railroad Company was very early drawn to the subject (1836) in a formal report of their engineer, Edwin F. Johnson, and that company afterwards adopted, under the information disclosed in the investigation made (which was very thorough), the gauge of 6 ft., or what is commonly termed the broad gauge. Other companies, under a less intelligent view, blindly persisted in adhering to the accidental gauge of the Liverpool and Manchester road of 4 7-10 ft., or, with small foresight, adopted an intermediate gauge. Under this state of things the gauge which has come to to be the most common in the Northern and Middle States of the Union is that of the New York and Pennsylvania Central roads, which have the gauge of the Liverpool and Manchester of 4 7-10 ft. A gauge which was derived from the tread of the coal carts in use on the English tram-roads, and was not the result of any careful investigation as to its fitness for railways operated by steam-power under a general system, but which answered very well for Great Britain, where great speed and accommodation were not called for, the average distance travelled by passengers there not exceeding about 15 miles each on the railways.

Here, however, the circumstances were altogether different, as an entire continent, 3,000 miles broad, was to be traversed, requiring the highest speed practicable and the greatest accommodation for both freight and passengers. Even in England the gauge of 4 7-10 ft. was thought too small by many of their most intelligent men, and the line from London to Bristol was built with a gauge of *seven* ft. This alarmed the narrow gauge interest, which, like the unfortunate fox in the fable, sought to get an Act of Parliament compelling all railway companies in the country to conform their roads to the gauge of 4 7-10 ft. Parliament appointed a commission of able men to investigate and report. The commission could not pronounce against the 7-ft. gauge, even for England, but they said that if uniformity was necessary or desirable, the gauge of 4 7-10 ft. was probably the best, because most of the roads then in operation in that country, were of that gauge. The facts and evidence educed by them, and arguments advanced, mainly favored a broader gauge than 4 7-10 ft., and it is a fact, that on the gauge of 7 ft. a speed of 45 to 50 miles per hour was easily attained; but the advantage thus gained was probably in that country not equal to the inconvenience of a gauge differing from the other roads.

When a system was desired for Ireland, a territory of less extent than England, the gauge was fixed, not at 4 7-10 ft., but at *five* and *one-half feet*, and the same was subsequently adopted for the Canadas,

and since for the British Indies and Australia. Our English neighbors, it would seem, had begun to realize fully the fact that a system which might answer very well for the small space covered by the "fast anchored" isle, might not be the best suited for a continent, and they were not alarmed by the denunciations of the narrow gauge interest in this country, which have been very bitter against any gauge wider than 4 7-10 ft., and have so continued to this day, to the great and lasting injury of the railway system and the best interest of the country. The railway and the steam locomotive together constitute one machine, the excellence of which depends on the proper adaptation of the one to the other, and to the work to be done. The late Zerah Colburn, the able editor of the London journal of "Engineering," in the last edition of his treatise on the locomotive (1870), after a full consideration of its powers and capabilities, thus remarks:

"It would be a matter of very great convenience were the track wider than at present [that is wider than 4 7-10 ft.], and we believe that the experience of a dozen years at most, will determine it to be a matter of absolute necessity."

This opinion of Mr. Colburn was pronounced in England, and is the more valuable from the fact that he was at first, and for a long time, an advocate of the narrow gauge of 4 7-10 ft. for railways, and challenged the writer of this to a discussion of the subject in the columns of the "American Railroad Journal," N. Y., then edited by him. The opposition to the broad gauge has, in every instance known to the writer, been easily traceable to an interested and selfish source, but it has, doubtless, in many instances, proceeded from ignorance. The wider gauge would doubtless suggest to one taking a superficial view, greater cost, both in building and in operating, and this seems to have been the case with a writer in the N. Y. "Sun" of April ult., who, after giving a very good outline history of the Erie Railroad, in which he states that it moved last year the immense number of 4,852,565 tons of freight, valued at $1,000,000,000, asks the question: how can this traffic be made to pay? A question which he answers in part (without showing that it does not pay on any reasonable cost of the road) by the statement, which is neither theoretically nor practically true, that "the exceptional gauge of the road, 6 ft., largely increases the cost of operating it."

For main lines of railway and main branch lines there cannot be any reasonable doubt of the superiority of the gauge of 6 ft. over any lesser gauge; but the question is being mooted in Europe, and beginning to attract attention in this country, whether for the remote and smaller branches, a lesser gauge of say 3 or 3½ ft., cannot be profitably used; and it will not be denied that it may be for short branches leading to mines or factories, and in sections difficult of access, where the work to be done is limited, and where rapidity of transit is a secondary consideration; but these cases will be very rare. The published statements of the advocates of these narrow roads, show an imperfect comprehension of the subject, and that there is danger of the public being misled to its injury.

Unless facts and figures both greatly deceive, the 6 ft. gauge is, as shown, decidedly superior to the 4 7-10 ft. for roads doing the work of the great railway lines of the country. A gauge of 3½ ft., such as is now being proposed in several localities, bears somewhat the same proportion to the 4 7-10 ft. as the latter does to the 6 ft. If, therefore, the 3½ ft. gauge is superior to the 4 7-10 ft. as claimed, it follows, that the latter is inferior to both the 6 and the 3½ ft., and that the country has been induced to adopt a gauge for a large majority of its roads, the least to be commended of any. The fact is, however, that a Tom Thumb road of 3 or 3½ ft. gauge is far less capable of doing the work our railways are being called upon to perform, than the 4 7-10 ft., which in turn, as has been shown, is inferior to the 6 ft. gauge, and this fact will be still more apparent when in a few more years, 30 at most, our population shall be doubled, and the exchangeable wealth of the country within its borders probably quadrupled. Our leading roads will then have work enough, and more than enough, to do, and it is not too soon for the two great lines, the New York and the Pennsylvania Central, to consider whether it is not best for them to prepare to adopt the gauge of 6 ft., and demand (for if they speak at all, they should speak now) that the Northern Pacific road, the great highway of

the Continent, shall also have the same gauge.

When the building of railways was commenced from Chicago west, an effort was made to have all the railways north and west of that point of the better or Erie gauge of 6 ft., and the Chicago and North-western road, then under a different name, was commenced with that gauge in the hope that other companies would join in its use, which they declined to do, and the consequence is an inferior system of railways for the valley of the upper Mississippi. It is very unfortunate that neither the promoters of railways in that region nor their professional advisers were able to realize the importance of the plan thus recommended and commenced; and at a later date, when the granting of a subsidy to the Union Pacific Railroad Company placed it in the power of a Government cabinet officer, by a clause in the act to that effect, to fix the gauge of that road, instead of causing an investigation of the subject by the ablest men of the profession, he merely asked the opinion of 2 or 3 presidents of railway companies interested in narrow-gauge lines leading towards the Union Pacific road, and at their suggestion, it would seem, pronounced in favor of the narrow gauge. It may be that a right judgment was given in this case; but it is not creditable to the country that so important a question was in such manner disposed of, and that no proper investigation was made by competent and disinterested men of the profession.

The country is now engaged in opening another great transcontinental line to the Pacific, of far greater ultimate importance than the one now in operation.

This line (the Northern Pacific), from its position and other circumstances, is certain to be the great thoroughfare *par excellence* between the Atlantic and Pacific Oceans, and being of so great extent, and owned by one company throughout, the best gauge should and may be adopted irrespective of connections with other roads.

Notwithstanding the proven superiority of the broad over the narrow gauge, as above, it may be claimed by some that the practical operation of the only great main line, the Erie, built on that gauge, has not fulfilled the expectations formed in regard to it. This, if so, is not because the road does not possess the superiority claimed for it, but because the circumstances have been such as to prevent that superiority from becoming manifest.

Upon our main lines of railway various causes have from time to time operated to add to or lessen the revenue upon them, and the cost of working them. The Erie Railroad has been peculiarly subject to causes of this character. The period of its construction was greatly lengthened by the want of sufficient means to prosecute it, and the formidable opposition which it experienced from the more densely populated and wealthier portion of the State to the north of it, and of the country to the south of it, delayed and embarrassed its construction, and the interest account and discount on its bonds and costs were largely increased. The country traversed by it was very much of it unsettled, and time was required to bring in a population to its support. The ground also was very difficult in many places, and the work heavy and costly. The rise and fall per mile exceeded greatly that upon the northern route from New York city to the lakes by the Hudson and Mohawk valleys, etc., and the gradients were higher, and not distributed in the best manner to economize the cost of operating. The natural difficulties were greater, and artificial ones were created by injudicious management. The adaptation of the motive power and the rolling stock to the road and the gauge was not effected in the best manner, and because of frequent change in the management, and employment of incompetent superintendents, who should, in all cases, be regularly educated and trained civil engineers. This state of things, it is understood, was also aggravated by the interference of meddlesome officials, evils under which the most of our railroads are more or less laboring.

Among such a variety of causes, all of them affecting more or less the cost of operating the Erie road, it is not possible to determine with certainty, or to express by figures derived from practical results on that road, the degree or amount of benefit derived from the broad gauge. It is safe to assume, however, that it has been a benefit, and a very considerable one, and has greatly aided it in competition with other and rival lines of road.

All who have travelled upon it speak in unqualified commendation of the comfort afforded by the equable and steady movement of the cars upon it. Of the other advantages, the traveller would not be likely to be cognizant; but they must have been very great, under a fair comparison of circumstances with other lines having the narrow gauge. Some discomfort during a day's ride or so on a railway, is not of so much account to the majority of travellers; but when the journey amounts to a number of days, or of days and nights in succession, it is different, and of still greater consequence where there is competition with other similar lines of communication.

The arguments originally advanced and evidence adduced in favor of the broad over the narrow gauge, have not been disproved or refuted. The subject has undergone some investigation since, and with a similar result; but the broad gauge has not been adopted, as it would have been in many cases, for reasons which it would not be creditable to our railway managers and to the profession to state. But for this, the gauge of 6 ft. would now have been the gauge of nine-tenths of the railways of the land, and the country would have reaped a corresponding benefit.

In no part of our extensive country has there been so little excuse for an adherence to the narrow gauge, as in the region west of the Alleghanies, where the country is virtually one vast plain, and where the greatest speed, power, and comfort in the construction and operation of railways were demanded, and could easily have been attained.

Not a railway track, we repeat, should have been laid west of the Alleghanies—and certainly none west of Lake Michigan—of a less width than 6 ft.; but the causes named, and the supineness and indifference of the public, have permitted the evil of the narrow gauge to be carried far beyond that limit, and by one line, as stated, even to the Pacific.

It is fortunately not too late to prevent a similar great mistake from being made on at least two of the great transcontinental lines—the Northern and the Southern. Either of these lines is long enough, and far enough removed from any parallel lines, to be treated as independent lines, and they should be built in the best manner, and upon the most approved plan of construction; and if the broad gauge is superior to the narrow, as it has been shown to be, they should be built with that gauge.

In a comparison of the cost of road and equipment on the two gauges and other considerations, it cannot be denied that the result is favorable to the broad gauge, and the cost is only materially greater upon the latter when advantages are sought to be attained which the narrow gauge cannot furnish.

Upon the Northern Pacific Railroad the prices of the ruling items of the cost will vary in different localities, but the average cost of timber ties will be less than the amount stated above, the Company being allowed to obtain them from the public lands free of charge, while the cost of iron may be somewhat greater, leaving, however, it is believed, the balance of the cost, for the entire line, in favor of the broad gauge; but should the cost be the same, there will result a benefit in the superior character of the road, a benefit which will be realized in the saving in cost of repairs and in operating, and in the greater revenue derived from it, since the Company will be able to offer to the travelling public a means of communication superior in speed, safety and comfort, to any other, considerations of the highest importance on so long a line as 2,000 miles.

That the broad gauge should be adopted by the Northern Pacific Railroad Company, does not, it is believed, reasonably admit of a doubt, and it would be cheaply purchased by some increase in the cost, if that is necessary.

The character of the Northern Pacific road as a great highway between the two principal oceans of the globe, and between two continents where the population is the most dense, demands that locomotion upon it be rendered as perfect as possible. It cannot be made too rapid and easy, and should be effected, if to secure it, greater cost is required; but when it can be obtained at probably no greater cost, it will be a very great mistake not to obtain it.

The necessity for rapid transit is obvious from the effort made the past and present season to convey passengers between New York city and Chicago in 24 hours, or at the average speed of 40 miles per hour. Great as this need is, it is far greater for

the attainment of a speed of 50 miles per hour between the two oceans.

The speed of 40 miles per hour is found to be very trying to the narrow gauge and its rolling stock, causing a rapid deterioration of both.

It will not be attempted to fix the limit beyond which there is no gain from the expansion of the gauge on the great main lines of railway. The experience in England shows that the limit is not exceeded in a width of 7 ft. and it certainly is not in a gauge of 6 ft.

The practical operation of the two gauges shows clearly a gain in speed in favor of the broad over the narrow gauge, and there is no mistake in saying that 45 or 50 miles per hour average speed on the Northern Pacific Railroad for at least one daily train each way, will justify, to obtain it, a transfer to a different gauge.

50 miles per hour is a saving of 1-5th in time over 40 miles per hour, but even a gain of half that amount may be all important in a close competition with other lines or routes, and to satisfy the requirements of commerce.

Notwithstanding what has been said of the extent of the Northern Pacific road and large surface to be covered by its branches or tributaries, all of the same gauge, it may be urged that great inconvenience and some expense will be caused by reason of connections with lines leading from the eastern portion of the road to the Atlantic seaboard.

The existing lines in this direction are mainly narrow-gauge lines. The others, omitting the 4 ft. 10 in. gauge of Ohio, are either 6 ft. or 5 1-2 ft. The Canada roads are of the latter gauge. The Erie Railroad and its branches are 6 ft. It cannot be long before the latter will be carried to Chicago, and probably, in less time than the Northern Pacific will be open to the Pacific, if improper and unwise influences do not continue to prevail against it.

From Chicago to Minnesota a third rail will be needed on the portions built, and those to be constructed may have the broad gauge at first, the third rail to be added if found expedient. The Canada roads, if changed at all, will doubtless be to the 6 ft. rather than the 4 7-10 ft., but no change will probably be made in them, if the Northern Pacific adheres to the 4 7-10 ft. Canada, in that case, will have the best line of transcontinental railway within her own borders, and the great thoroughfare of the continent may pass to the north of us, for it cannot be asserted that the ground north of lakes Huron and Superior is impracticable. It is difficult, it is true, but the superior character and facilities afforded by the Saskatchewaw valley and other portions of the route, will make amends for a vast deal that is difficult and expensive north of the lakes; and that line, as a medium of communication with Eastern Asia, will be shorter, and it will have a terminus on the Pacific, in a temperate latitude.

The Northern Pacific Company can only attain and maintain the ground of superiority by adopting the 6 ft. gauge, which it should do at once, not hesitating for a moment, because of the cost of changing the small amount of track they now have in Minnesota, from the narrow to the wider gauge. The best interest of the Company and of the country demands the change, for in this respect the two are inseparable, and if made, other lines, if they deem a conformity to the same gauge important, will also change. The New York Central, in particular, occupying, as it does, the ground between the Canada and Erie lines, will conform to the wide gauge, and thus in time, by a judicious action of the Northern Pacific Company, the whole northern portion of the country will come in possession of a superior system of roads having the uniform gauge of 6 ft.

These changes, which are very sure to follow the adoption of the right gauge on the Northern Pacific Road, are not essential in their bearing upon the business of that road, for it is very easy to show that, upon a road of the great extent of the Northern Pacific and its branches, it will not be for the interest of the Company or its true policy to permit its cars and engines to pass beyond its own control on to other roads; neither will it be necessary or expedient, but a great injury, to admit upon its tracks the cars and the engines from other roads.

Under a moderate estimate the Northern Pacific Railroad Company will, in a few years, have under its management, no less than about 2,500 to 3,000 miles of railway, with a rolling stock consisting, probably, of not less than 1,000 locomotives and nearly 20,000 freight and passenger cars. This surely will be a concern large enough and complicated nouugh to be confined to one manage-

ment or control; and if but one change or transfer of passengers and freight is made in the long distance between the Atlantic and Pacific Oceans, at St. Paul, for instance, it will not be felt, nor can it be measured as an inconvenience of any account.

The centre of population for the entire country east of the Rocky Mountains, having direct and frequent communication with the Northern Pacific Railroad, is now in Eastern Ohio, and is moving steadily in the direction of the southern extremity of Lake Michigan. A very large portion of the travel and traffic over the Northern Pacific Railroad will be to and from the densely peopled region between the Alleghanies and the Mississippi river, and hence St. Paul, and particularly Chicago, must become leading points for the distribution of that traffic, and of breaking of bulk; and in this particular, when Chicago is made the place of junction of the river and lake navigation, by the improvement of the Illinois and Michigan Canal to that extent as to permit river steamers to pass through it, it will become a very great point for concentrating and distributing the trade of the interior west of the Alleghanies. There will, without doubt, be other points of the same character for that portion of the traffic seeking lake navigation, and Milwaukie, and Green Bay, and Mackinaw, on Lake Michigan, and the western extreme of Lake Superior, will be among the principal of those points.

All of the heavy agricultural and mineral and timber products from the vast region tributary to the Northern Pacific Railroad and its branches, which, on their way to an eastern or southern market, will seek the cheaper or more convenient navigation of the lakes, or of the larger rivers intersected by the road, will be brought to those navigations without change of gauge; but if this were not the case, the superiority of the broad gauge, used as it would be for a mean distance of 1,000 miles for the conveyance of those products, would fully justify a single transfer from one gauge to another, and leave a large balance both of time and money in favor of the broad gauge. It is believed that an addition of 8 to 10 miles per hour to the average speed for passengers, and the great saving in wear and tear under the same speed, will be cheaply purchased at the cost of 1 or even 2 transfers.

The Northern Pacific Railroad, while it will be more important and efficient, if rightly built, equipped, and managed, than any other transcontinental line, in securing to our people the trade of the Pacific, which is yet to be, for obvious reasons—viz., the dense population and advanced civilization of Eastern Asia, and low price there of human labor—the most profitable theatre in the future of ocean commerce, is also a part of a line or lines traversing the entire space from ocean to ocean, over which, if it be properly constructed and operated, will pass a very large portion of the travel between Europe and Eastern Asia. For this business, which will be very large, the route by the Suez Canal, and the lines of railway which will ultimately be extended eastward from Europe, or from the Mediterranean, will be competitors; and hence the greater necessity of so building, equipping, and operating the Northern Pacific Railway, that it shall not be excelled in the essential qualities of speed, power, economy, and comfort, by any other similar medium of communication. This is of the utmost importance, in view of its true character, which is so far above and beyond that of a great national work as to be the highway over which will pass many thousands of persons annually, from the most remote portions of the globe.

In conclusion, it may be stated that England gave to France and Belgium the accidental gauge of 4 7-10 ft., which was accepted without proper investigation, just as it was accepted by certain leading railway companies in this country; 5 ft. appears to be the gauge adopted in Switzerland. When Russia commenced her system of railways, she sent the Chevalier Von Gershier, a most able and accomplished engineer, to examine the railways of England and of this country. He did so, giving much time and labor and thought to the investigation; and on his return, recommended the gauge of 6 ft. for the Russian roads, and the road from St. Petersburg to Tzarsko-Selo was built with that gauge. Subsequently, the Russian Government employed an American engineer, and on his recommendation changed the gauge of the roads to 5 ft.

It is now understood that several leading engineers in Europe, dissatisfied with

the narrow gauge of 4 7-10 ft. or 5 ft, are seriously considering the question of recommending the gauge of 6 ft., as the best uniform gauge for the entire of Northern Europe and Asia.

FULTON.

THE MONT CENIS TUNNEL.*

From "Engineering."

Allusion was made in the last article to the elevated temperature, and to the vitiation of the air in the tunnel. These two causes excluded the possibility of the use of steam-worked machinery. Had this motor been used it ought to have been produced on the spot, because steam cannot be transmitted to considerable distances, without condensing; and as for the production of steam, fire is wanted, the surrounding temperature would have been insupportable, and would, further, through the absorption of oxygen, have made the air totally unfit for respiration.

Further, work is synonymous with heat produced, and hence the work itself, done by the machinery, would have contributed to render the temperature unbearable, had not the heat developed been counteracted by the motive power itself, which produced the work. For all these reasons it was self-evident that if mechanical means were to be used (and the work could not be accomplished without them), the motive power of the machinery employed was to be produced outside the tunnel, and carried along in the tunnel to the very spot where machinery was to be applied.

This problem had but one solution, which consisted in the application of compressed air as a motive power. This solution seems self-evident at first sight, because the application of compressed air as a motor is not a new idea nor a new invention.

Father Hall, a Hungarian Jesuit, in the middle of the eighteenth century, by means of a waterfall, guided compressed air in a tube to a recipient, from which this compressed air, passing in a second chamber, raised and discharged the water in the mines of Selmecx (Schemnitz).

Further, we remember that Montgolfier invented the hydraulic ram, by which he utilized the *vis viva* gained by water in its fall. But the application of these ideas to the production of mechanical work for the Mont Cenis tunnelling, had to meet with many objections, and great difficulties. The difficulties not only consisted in the invention of compressing machinery capable of compressing the immense quantity of air wanted; they also arose from doubts on the possibility of constructing large hermetically closed recipients, such as would not allow the digression of the air.

Experiments had to be made on this subject, and a recipient was erected at Bardonnèche. It was filled with air compressed to 6 atmospheres, and was left 24 days untouched. Fortunately, only a very small loss was detected as having taken place, which did not even amount to $\frac{1}{5000}$th part of the daily production.

It was objected that the transmission of compressed air to great distances, for the purpose of moving machinery, would hardly be possible, because of the loss of the pressure of the air produced by its friction along the conducting tube. This objection was considered a very serious one, as it was stated by great mathematicians, who made out apparently correct theories on the action of gases through long tubes. Further, several unsuccessful attempts had already been made to transmit compressed air, by Wilkenson and others.

It is true that Girard, and later, D'Aubuisson and Marot, and again, the celebrated Poncelet and Peclet were more successful in there experiments; they were not sufficiently so, however, to decide absolutely the case in favor of the possibility of the undertaking.

By order of the Italian Government, experiments were made on this subject, and more especially on the hydropneumatic compressor proposed by Messrs.

* In the formula on lines 15 and 25 of the third column of page 180 of our last number, "log. should be "hyp. log." The formula on line 30 of the same column also should read $t = a + t_1 = 273 + t$, the signs t and t_1 in this formula standing respectively for the *absolute* temperature of the air and the temperature expressed in the ordinary way, these temperatures being taken in degrees of the Centigrade scale. Also on line 10, from the bottom of the second column of page 180, "65.7 in." should be "65 ft. 7 in."

Sommeiller and Grattoni. The results of these experiments may be summed up in the annexed Table.

From this Table we see that for a length of 7,108 yards, with tubes of $3\frac{5}{16}$ in. diameter, supposing the original velocity per second to be 16 ft. $4\frac{3}{16}$ in., the loss of pressure at the end would only be $39\frac{1}{16}$ in., that is, about $1\frac{1}{4}$ of an atmosphere. Putting the initial velocity only at 13 ft. $1\frac{7}{16}$ in., the loss of pressure would be reduced to $27\frac{5}{8}$ in. or $\frac{9}{10}$ths of an atmosphere, and if we suppose the tube to have 20 per cent. greater diameter, the loss would still be reduced by the half of this latter loss.

Loss of Pressure in 1093.6 Yards in Inches of Mercury.

Diameter of the tubes.....		in. $3\frac{5}{16}$	in. $5\frac{7}{8}$	in. $7\frac{1}{4}$	in. $9\frac{13}{16}$	in. $11\frac{13}{16}$	in. $13\frac{3}{4}$
Initial velocity per second.	ft. in. 3 $3\frac{1}{4}$	$\frac{16}{64}$	$\frac{5}{32}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{5}{64}$	$\frac{5}{64}$
	6 $6\frac{1}{16}$	$1\frac{1}{32}$	$\frac{45}{64}$	$\frac{23}{64}$	$\frac{7}{16}$	$\frac{23}{64}$	$\frac{5}{16}$
	9 $10\frac{1}{16}$	$2\frac{7}{16}$	$1\frac{21}{32}$	$1\frac{7}{32}$	$\frac{53}{64}$	$\frac{43}{64}$	$\frac{45}{64}$
	13 $1\frac{7}{16}$	$4\frac{1}{4}$	$2\frac{53}{64}$	$2\frac{1}{8}$	$1\frac{11}{64}$	$1\frac{27}{64}$	$1\frac{7}{32}$
	16 $4\frac{3}{16}$	$6\frac{37}{64}$	$4\frac{13}{32}$	$3\frac{5}{16}$	$2\frac{11}{64}$	$2\frac{13}{64}$	$1\frac{21}{64}$
	19 $8\frac{3}{16}$	$9\frac{11}{64}$	$6\frac{9}{64}$	$4\frac{29}{64}$	$3\frac{15}{64}$	$3\frac{5}{64}$	$2\frac{11}{64}$

The final results of the experiments alluded to above, are shown in the following Table :

Area of the orifice.	Velocity per second.				Gauge at the end of the tube.	Loss of Pressure.	
	In the tube.		When issuing.			Observed.	Deduced from the curve of interpolation.
Square inch.	Feet.	Inches.	Feet.	Inches.	Inches.	Inches.	Inches.
.0281	3	$3\frac{3}{8}$	488	10	$14\frac{7}{8}$	.1525	.1525
.0983	10	$5\frac{3}{16}$	473	$0\frac{7}{8}$	$14\frac{13}{16}$	2 0472	1.7656
.0983	11	$5\frac{7}{16}$	501	$11\frac{5}{8}$	$14\frac{25}{64}$	3 1093	2 125
.0983	11	$9\frac{3}{16}$	526	$10\frac{5}{8}$	15	2 7187	2 25
.0983	13	$5\frac{9}{16}$	630	$4\frac{3}{4}$	$14\frac{11}{16}$	2 3936	2.875
.1264	14	$5\frac{1}{4}$	495	1	$14\frac{7}{8}$	3 2677	3.344
.2776	33	$3\frac{7}{8}$	526	$2\frac{3}{4}$	$14\frac{25}{64}$	15 3906	15 2031
.4844	49	$6\frac{1}{8}$	448	2	$14\frac{3}{4}$	35 5468	35.5468
.7639	60	$6\frac{3}{4}$	347	6	$14\frac{9}{32}$	61.4218	61 4218

The preliminary results observed at Bardonnèche confirmed those obtained by the experiments we have alluded to. In the Table given above we find that for a tube of $7\frac{7}{8}$ in. diameter, the air being compressed at 6 atmospheres, and the velocity being at the commencement $39\frac{3}{8}$ in. per sec., the compressed air would lose for every 1093.6 yards, a part measured by a column of mercury of $\frac{1}{8}$th of an inch in height. Comparing this loss with the atmosphere, the loss would be represented by $\frac{8}{760}$, or $\frac{1}{127}$th of an atmosphere for 1.24276 miles. Now when these tests were made at Bardonnèche the length of the tube conveying the compressed air was precisely this length. It had a diameter of $7\frac{7}{8}$ in.; the velocity of the air at the origin was 3 ft. and $3\frac{3}{8}$ths in. per sec., and hence the volume of compressed air flowing out at the opening was 1.109 cubic ft. Nine perforating machines working together consumed 9531 cubic ft. every sec., and the loss of pressure at the extremity of the tube was found a little inferior to $\frac{1}{127}$th part of an atmosphere ; and hence the result deduced from the Tables was confirmed by those practically obtained at Bardonnèche.

It may be interesting to give here a few theoretical observations on the movement of gas in tubes, nor will it be out of place, the subject being closely connected with the motive power which was used to carry out the perforation of the tunnel under the Alps. Besides, compressed air as a

motive power, will no doubt receive very wide and important application in future, and hence mechanical and civil engineers cannot sufficiently study the questions which are connected with the important problem to the solution of which the possibility of the completion of the tunnel is owing.

Compressed air, and, indeed, almost all gases moving along a tube, encounters a certain amount of resistance owing to friction. If we represent by L the length of the tube, and D its diameter, the loss of pressure occasioned by the friction alluded to, is represented by

$$H-h=K\frac{L}{D}\frac{v^2}{2g},$$

where H and h are the pressures at the beginning and the end of the tube, measured in columns of the same gas, at the density it has at the section at which the velocity, v, is taken, and where K is a numerical coefficient (the coefficient of friction=0.0236), and g is the accelerating force of gravity.

Let H_1, H^1, and h be respectively the pressures in the reservoir at the starting, near the orifice of outflow, and externally, measured in columns of gas of the density of the gas in the reservoir, D and d being the diameter of the tube, and of the orifice by which the gas flows out; further, ϕ ψ, the coefficients of contraction at the entrance into the tube, and at the orifice of escapement, and K that of friction, as said above; v the initial velocity in the tube, $a+t^1$ the absolute external temperature, and $a+t$ the absolute temperature of the reservoir.

The general equation of the motion of the gas in a rectilinear tube of uniform section will be

$$H-h=\frac{v^2}{2g}\left\{\left(\frac{1}{\varphi^2}-1\right)\times K\frac{L}{D}+\frac{D_4 H(a+t^1)}{\psi^2 a^4 H^1(a+t)}\right\}$$

To obtain the pressures measured in columns of mercury, if P, P^1 and p are the heights of mercury equivalent to H H^1 and h of gas; and δ being the tubular density of the gas, we shall have

$$H.\delta\times 1{,}3\frac{P}{0{,}760}\frac{a}{a+t}=13596\,P,$$

whence

$$H=7990\frac{a+t}{a\delta},$$

and

$$H-h=H\left(1-\frac{h}{H}\right)=7990\frac{a+t}{a\delta}\left(1-\frac{p}{P}\right)$$

and the equation of the movement of gas shall become

$$P-p=\frac{a\delta P}{7990(a+t)}\left\{\left(\frac{1}{\varphi^2}-1\right)+k\frac{L}{D}+\frac{D^4 P(a+t^1)}{\psi^2 a^4 P^1(a+t)}\right\}\frac{v^2}{2g}.$$

If we wish to have the volume of the outflowing gas at every second, respectively at the temperatures and pressures P and t^1, and p and t^1, they will be given by

$$Q=\pi\frac{D^2}{4}v \text{ and } Q^1=\pi\frac{D^2}{4}\frac{P(a+t^1)}{p(a+t}v.$$

The exactness of these formulæ at low and middling pressures, has been sufficiently proved by the results of the experiments made.

To illustrate them, let us apply them to air moving in tubes of 0.01028 metre diameter, of the length between 0.07 and 18 metres, allowing the air to flow freely into the atmosphere under a constant pressure of one atmosphere, we shall have $\delta=1$ and $\psi=1$ and P^1 very approximately equal to P; further assuming $\frac{1}{\phi^2}-1=1.475$, *i. e.*, $\phi=0.636$ and $t=t^1=20°$ $\frac{1}{a}=\frac{1}{250}$, instead of $\frac{1}{273}$ in order not to neglect the aqueous vapors existing in air, we shall have

$$Q^1=410{,}305\,\pi\frac{D^2}{4}\frac{P}{p}\sqrt{\frac{1-\frac{p}{P}}{2.475+0{\cdot}0236\frac{L}{D}}},$$

in which we shall make $\frac{p}{P}=2$ and D = 0.01082. The following table gives the results calculated with this formula by M. Cavallero:

Length of the tube (L).	Values of Q^1 (volume of the out-flowing gas) by experiment.	Values of Q^1 by calculus.	Differences.
Metres.	Metre cube.	Metre cube.	Metre cube.
18	0.00724	0.00719	0 00005
9	0.00989	0.00989	0.00000
4.50	0 01380	0 01331	0.00049
2.25	0 01721	0.01727	0.00006
1.125	0.02032	0.02127	0 00095
0.562	0 02480	0 02471	0.00009
0.281	0.02760	0.02720	0 00040
0.14	0.02869	0 02876	0.00007
0.07	0 02869	0 02965	0.00096

From the experiments made on this

subject, the following empirical has been deduced :

$$v = \frac{2225}{\frac{D^2}{4}\pi}\frac{p}{P}\sqrt{\frac{D^5\,(F-0{\cdot}76)}{L+42\frac{D^5}{a^4}}}$$

which serves to the determination of the velocity, v, at the origin of the tube.

The experiments made on the hydropneumatic compressor of Messrs. Sommeiller and Grattoni (to which I alluded in my last letter), have proved that the formula given above does not hold for high pressures.

The same fact can be demonstrated theoretically. The loss of pressure owing to friction is expressed by

$$\frac{P-p}{P} = \frac{a\,\delta}{7990\,(a+l)}\,K\,\frac{L}{D}\,\frac{v^2}{2g},$$

whence

$$P-p = \frac{a\,\delta\,K}{7990\,(a+l)}\,P\,\frac{L}{D}\,\frac{v^2}{2g}.$$

If we now consider separately two portions of tube of the respective lengths of L_1 and L_2; and if P and P^1 and P^1 and p the initial and final pressures of the two portions, v and v^1, the velocities at the end of the lengths, L_1 and L_2, we shall have, when applying the last formula,

$$P-P^1 = \frac{a\,\delta\,K}{7990\,(a+l)}\,P\,\frac{L^1}{D}\,\frac{v^2}{2g},$$

and

$$P^1-p = \frac{a\,\delta\,K}{7990\,(a+l)}\,P^1\,\frac{L^2}{D}\,\frac{v^2}{2g}.$$

$$P-p = \frac{\frac{a\,\delta\,K}{7990\,(a+l)}}{2\,g\,D}(P\,L_1\,v^2+P^1\,I_2\,V^{1\,2}).$$

The temperature of the tube being constant,

$$P\,v = P^2\,v^1,$$

hence

$$P-p = \frac{\frac{a\,\delta\,K}{7990\,(a+l)}}{2\,g\,D}(L^1\,v+L_2\,v^1).$$

Now, as

$$v^1 = v+(v^1-v),$$

we have

$$P-p = \frac{a\,\delta\,K}{7990\,(a+l)}\,P\,\frac{L}{D}\left\{1+\frac{L_2\,(v^1-v)}{L\,v}\right\}\frac{v^2}{2g},$$

which is different to the one found above for low pressures, and the difference is directly proportional to the difference between P and P^1.

Before leaving this subject, I wish to lay before your technical readers some very simple formulæ presented to the Royal Lombard Institute by M. Cagnoni, which are probably unknown to them.

M. Cagnoni started from D'Aubuisson's simple formula:

$$A-a = 0.0238\,a\,\frac{L\,d^4}{D^5},$$

where a and A are the manometrical heights of mercury at the end and at the beginning of the tube; d the diameter of the opening of outflow, D the diameter, and L the length of the tube, putting D= 006m., and L=400m. (which were the conditions of the experiments made on Messrs. Sommeiller and Grattoni's hydropneumatic compressor) D'Aubuisson's formula becomes

$$a = A\frac{1}{1+123430000\,d^4},$$

when the results given by this equation were calculated, they were found two or three times higher than those the practical experiments gave.

M. Cagnoni then made the hypothesis that an elastic fluid, flowing out from a long tube of constant diameter, and under a permanent pressure, with velocity and density different in the various sections, would behave approximately as a liquid, which would have a uniform velocity equal to the medium of the velocity of the fluid corresponding to the extremities of the tube, and a uniform density also equal to the medium of the densities corresponding to the same extremities; starting from this hypothesis, M. Cagnoni deduced:

$$A-a = 0.000000103\,\delta\frac{L}{D}u^2$$

in which A and a are the pressures in metres of a column of mercury at the beginning and at the end of the tube; δ and u the media density and the velocity as explained above.

Applying this formula to the determination of the coefficient

$$0.000000103\,\delta.$$

M. Cagnoni found the following numbers, substituting for A, a and u, the values taken from D'Aubuisson's experiments,

$0.000000103\,\delta$	$= 0.0000001318$
	0.0000001311
	0.0000001317
	0.0000001325
	0.0000001352
medium value	0.0000001326

This would show that the formula under the above hypothesis is applicable to low pressures.

M. Cagnoni, however, comparing the results given by his formula with those obtained in the experiments made on

Messrs. Sommeiller and Grattoni's machine, proved that it is also very approximatively applicable to high pressures.

The following table clearly shows it:

Velocity at the origin of the tube.	Difference of pressure (A - a)	
	Obtained in practice.	Deduced from the formula.
1.012	0 0039	0.0046
3.197	0 0457	0.0459
3.604	0.0577	0.0571
4.106	0.0738	0.0758
4 415	0.0853	0 0877
10.157	0.3660	0.4641
15.100	0.9030	1.0260
18 460	1 5560	1.5330

The formula itself is transferred

$$A-a=0.0818\,\frac{b+a}{(b+a_1)_2}\,\frac{L\,d^4}{D^5},$$

introducing in it, instead of the medium velocity, a function of the diameters D and d of the tube, and of the opening of outflow and in which b=0.76 a_1=½ (A+a), L=length of the tube, and A and a keeping their former meaning.

Introducing further the quantity Q of fluent air reduced to the volume of ordinary atmospheric density, M. Cagnoni deduced

$$(b+a)^2=(b+a)^2+M\frac{L}{D^5}Q^2,$$

in which M is a numerical coefficient which may be taken=0.0000002567.

THE ART OF SPOILING PUBLIC BUILDINGS.

From "The Building News."

To those who have been behind the scenes there is something amusing in the reasons popularly assigned for our great architectural failures. One writer will tell us that the English nation has no artistic powers. We once, it is true, produced such trifles as the choir of Lincoln, the octagon of Ely, and the spire of Salisbury; we covered the land with abbeys and parish churches which are not quite unworthy of notice, and we produced a quantity of domestic architecture which, if it is not showy, at any rate cannot be called coarse or vulgar. No matter; we *are* inartistic, and we ought to be proud of it. So our journalists frequently assert, not of course in so many words, but in that form of modest confession which cloaks the most outrageous type of vanity, the vanity which feeds even on weakness and incapacity. "Nature has not endowed us," we are told, "with the artistic talent of the French, the plodding industry of the Germans," etc., etc.; and there is an underhand implication throughout that all such qualities as these are very poor things, only fit to be despised as unworthy of our transcendent greatness. Another writer, with a little more discernment than the last, looks at our architectural failures with regret. He sees that we did not always fail, and he is sorely puzzled to find why we should do so now; and at last, not being able to discover any sufficient reasons, he ends by setting it all down to chance. We have had a run of bad luck, he fancies, in our public works; some day the tide may turn, and we shall do better. It is a matter of accident; we have been unfortunate, and there is no more to be said about it. Now for our own part we entirely dissent from both these theories. Our public buildings, as we believe, are spoilt neither by accident nor by incapacity, at least on the part of the nation at large. The spoiling of them is an ingenious and complicated process, which may properly be called an art, and of all the arts it is perhaps that which in modern England flourishes the most.

The best way of explaining the system will be by example. Suppose, then, that it is a new town-hall or vestry-hall, or church or chapel, that is wanted, and trace the common methods of proceeding. These methods, indeed, are not quite universal, and so our public architecture is not universally bad. In church building, particularly, the influence of art education amongst the clergy helps to modify them; and whatever our churches may be as regards convenience, in point of art they are often above the average. But we will take an average case, where the management is in the hands of an ordinary committee. If none of the members of this committee know anything about the design of buildings, the prospect is bad enough; but shou[illegible]

there happen to be a "practical man" amongst them the case is ten times worse. For the truly practical man we have the highest respect. If he were only a practical mason or carpenter we would go to him for masonry or carpentry facts within his own knowledge before all the theorists in the world. But the most thoroughly practical man is only an authority in questions to which his practice has extended; and the practice of masonry or carpentry is but a small portion of architectural practice as a whole. The sort of "practical man," however, who generally gets on a committee does not deserve even this amount of respect. Nine times out of ten he is an impostor, empty, plausible, and loud. He has, perhaps, got a few technical terms by heart, or he may have spent a year or two of his youth in a builder's office, or possibly he once drew a house plan which, with sundry indispensable modifications, was ultimately carried into execution. For these or some similar reasons he is held in great veneration by his colleagues; his opinion, which he is never backward in giving, is invested with mysterious weight, and, tacitly promoted to the leadership, he becomes the one-eyed king of the blind. The committee, we will suppose, have obtained a site; their next step is to procure designs. Each member has an architect whom he wishes to recommend, and, as it is impossible to come to a unanimous choice, it is decided to invite a public competition. The practical man draws up the conditions, which are chiefly remarkable for demanding more accommodation than can be expected for the money. Plans, of course, are to be sent in under mottoes, and the author's names are supposed to be totally unknown. It is very remarkable, under these circumstances, that each architect's design should exercise a special attraction on his own private friends; that Mr. A., the chairman, for instance, should think no drawings comparable to those which ultimately prove to have been the work of his own son-in-law, and that Messrs. B., C., D., etc., should each and all show inexplicable affinities of a corresponding kind. There must surely be some occult influence conveyed into the paper from the fingers of the draughtsman, which can only operate on those who are in sympathy with him—a kind of "psychic force," in fact, like that now being investigated by Mr. Crookes. But though everybody on the committee may have his own preferences, everybody, it is plain, cannot have his own way. They must agree on some one design which can command a majority; and so they proceed to discuss what have been sent in. Design No. 1 is very plain; its architect adhered to the conditions and kept within the sum allowed—so he is dismissed at once. No 2 is admitted to be "pretty;" but the practical man asks what need there is for all this waste of money at the sides and back; they only want a "front," and in search of a front they go on to No. 3. This is allowed by all, save a few fastidious members, to be the gem of the collection. It has a magnificent portico, with six Corinthian columns, an entablature with carved acanthus-leaf modillions, and a pediment with a small bull's-eye window in its centre. But this is not all. Contrast, as every one knows, is the soul of art; and what a contrast is here! Behind the Corinthian columns comes a 14-in. brick wall; behind the entablature, a cast-iron eaves gutter; and behind the pediment a hipped slate roof. Such a design could not fail of being adopted by acclamation; but alas! on turning to the plan, it is found too small. Carried away by the inspiration of genius, its author neglected the practical in pursuit of the ideal; he has enraptured the tastes of the committee and they give him a premium; but he has overlooked their requirements, and they cannot carry out his conception. With lamentation and regret they go forward, but the other drawings have almost lost their charm. They come at length on a plan which even they cannot help seeing is a good one; but then the elevation is not "pretty" at all. It is Gothic, and they might bring themselves to endure Gothic if there was plenty of tracery, and gablets, and pinnacles, and crockets; Henry the VII.'s chapel, they think, is very pretty, so is Bethesda Chapel, in the High street; but such Gothic as this they never saw in any chapel of their acquaintance. They accordingly vote it "heavy," and pass on—for heaviness, with committees, is the most unpardonable of sins. At length, puzzled and confused, they have gone through the whole collection. They would like the plan of No. 12, the front of

No. 3, and the interior, say, of No. 20. But to each of these designs, as a whole, there are strong objections; and they end, perhaps, by fixing on a set of drawings which nobody likes, simply because nobody has been able to point out any insuperable objection to them. Their author is accordingly appointed architect, and their committee pride themselves on having acted fairly and having resisted temptation. The next thing they do is to try and import the charms which have attracted them in other drawings into those which they have selected. The architect sees difficulties, and foresees a jumble. He argues, protests, and predicts disappointment. The practical man makes light of his objections, insists that the four designs can easily be amalgamated, and prepares, it may be, some marvellous sketches to show the way. If the architect is weak, the committee overpower him; he submits, perpetrates a jumble, and regrets it forever after. The practical man, having gained his point, rises higher than ever in general estimation, and is appointed supervisor and director of the works. As the working drawings proceed, he looks them through, thins the walls, ruins the details, and takes care that the sides and back of the building shall be sufficiently shabby. All this he does, not so much for the sake of saving money as for the sake of asserting a principle: the grand principle of heaping all the ornament on the front wall. He does not even grudge expense when a reasonable amout of ugliness is to be gained by it, and though he would strike out mouldings as a wasteful extravagance, he revels in lead flats, gutters, and parapets. The next thing is the receiving tenders for the works, which are all, of course, too high. The committee asked for too much in the first place; they rejected, in the second place, the few designs that were within their estimate; and so it is inevitable, as a result, that the cost should outrun their funds. Then comes the cutting down. The design, already half-starved, is now reduced to the extreme of emaciation. Every item on which a saving is possible is reduced; if there was a tower, the tower is omitted; if there was a portico, the portico is flattened into a row of pilasters, the walls become a little thinner yet, the roofs a little weaker, the whole construction a little more trumpery and poverty-stricken. The works go on; the practical man still broods, like a nightmare, over all; and the building turns out at last about as well as if he himself had designed it. Such is the history of many and many a structure, at whose incomprehensible wretchedness all observers (save English ones) stand amazed. Well they may be, for the production of such work would seem impossible if we had not long learned how to do it. It is no easy matter to turn out such public buildings as ours. It could not be done by tossing up for the design to be accepted; it could not be done by blindfolding a committee-man and adopting the first plans he laid hold of; it can only be effected by strenuous and unceasing effort towards the attainment of the lowest possible pitch of degradation.

Our example has been taken from the minor class of public works—from those which are rather local than national; but we manage the latter on just the same grand principles as the former. In great things as well as small, we follow one unalterable rule—that of setting everybody to direct what he least understands, and to do what he most earnestly protests against. If we have, by strange accident, a Minister of Public Works who is equal to his duties, we do not lose a moment in getting rid of him. London would not be London long, with such a man to direct her; make him an ambassador—nay, make him an admiral—rather than let him stay here. Have we an eminent Gothic architect appointed to design a most important building? The risk is imminent of his doing something creditable; our measures must be proportionately violent to hinder him. Compel him to work in a style he hates; even he may then keep our national reputation down to its traditional level. Such a feat as this, indeed, is not given to every man to do. A Prime Minister accomplished it once; but it is somewhat beyond the strength of the poor R.A. who has tried it lately. We venture to hope that the Law Courts may turn out somewhat differently from the Foreign Office, and that we may at last see an architect who, with all the plausible stupidity in England opposing him, will set our precedents at nought, and refuse to have any hand in spoiling work on which he is engaged.

REMARKABLE EXPERIMENTS ON STEAM BOILERS.

A series of very remarkable experiments has recently been commenced by the United Railroad Companies of New Jersey under the immediate direction and superintendence of Mr. Francis B. Stevens of Hoboken.

We are indebted to Professor Thurston of the "Stevens Institute of Technology," for the following account of the work done on the 22d and 23d November.

For a considerable time past Mr. Stevens has been collecting the steam boilers as they were removed, "worn out," from the steamboats of the above-named corporation, and subjecting them to a systematic course of experiment with the object of obtaining some reliable information upon the subject of steam boiler explosions.

Each boiler was subjected several times to hydrostatic pressure until ruptured, the position, character, *et cætera*, of the break being carefully observed and the boiler then repaired preparatory to another experiment.

This series of experiments afforded strong evidence that the stayed surfaces, which are usually the strongest portions of a new boiler, become finally the weakest in many cases.

In most of the instances referred to above, the stays and braces were the parts which gave way.

After this course of experiment was completed, Mr. Stevens, having been voted $10,000 by the United R. R. Companies for the purpose of prosecuting this work, transported the boilers to Sandy Hook and set them up—with the consent of the Secretary of War and of the President—upon the United States reservation, there to be exploded by steam pressure.

Mr. S. also built several boilers for the latter set of experiments, and set them with the others in an inclosure near the beach and at a considerable distance from any habitation.

The first experiments at Sandy Hook were made November 22, in the presence of a large party of invited guests, including many of our best-known civilian and naval engineers, railroad officials, Government inspectors, and other persons specially interested in the subject.

"*No.* 2" was the first boiler attacked. This boiler was built by Fletcher Harrison & Co., in 1858, and had been in service 13 years. It is an ordinary "return flue" boiler, 6 ft. 6 in. diameter of shell, and 28 ft. long. It was tested in September by hydrostatic pressure, giving way, by the breaking of a stay-bolt, at 66 lbs. After being repaired, it bore 82 lbs. at Sandy Hook, November 4th, without injury, and November 15th was again tested to 60 lbs. pressure.

Steam having been raised in this boiler, a heavy wood fire was built up in its furnaces, the doors were closed and the company moved off to the gauges, which were placed a considerable distance from the boiler enclosure. The gauges were well made and had been carefully tested and proven correct.

Steam rose steadily from a pressure of 60 lbs. to 90 in 18 min. At 92 lbs. leaks became plainly visible, and at 93 they had become so numerous and so large as to let off the steam as fast as generated, and after standing a short time at that point, the pressure gradually decreased, and Mr. S.'s workmen putting out the fires, the experiment came to an end.

"No. 6" was next tried. This was a new construction made as nearly as possible like the back end of the exploded boiler of the Westfield, merely a "water leg," with stays distributed as in the boiler of that unfortunate steamer. It is made of Abbott's best flange fire-box iron, 5-16 in. thick, and the stay-bolts were without nuts and of $1\frac{1}{8}$ in. iron. This "leg" was set in brick-work and fires built on both sides of it, the water-line being entirely above the fire surface. It had been previously tested without injury to 138 lbs. per sq. in., cold water pressure, and with 102 lbs. steam pressure.

During this experiment, steam rose from 4 to 20 lbs. in 10 min., from 20 to 40 in 6 min., from 40 to 80 in 7 min., from 80 to 160 in 9 min., and in 27 min. from the moment when the gauge showed 4 lbs., and at a pressure of 165 lbs., or a trifle over, a violent explosion occurred, tearing the "leg" into two parts, which were thrown far apart, and scattering the brick-work over a wide area of ground, portions of the latter falling among the spectators at the gauges.

The screw stay-bolts had drawn out and

the sheets had then been torn away from the rivets at their edges. Both halves were deeply dished, and around the points at which the stay-bolts had taken hold, the surface coating of oxide had been off along the lines of compression, where the metal had *wrinkled*, and the delicate lines thus marked presented a curiously interesting appearance, and bore some resemblance to the magnetic spectra described by physicists.

Next day, November 23d, a third boiler was experimented upon. This boiler, "No. 3," was built in 1845 by T. F. Secor, and had been in use 25 years. The U. S. Inspector's certificate allowed, at the time of its removal, 30 lbs. pressure to be carried. It was a "return tubular" boiler, 12 ft. wide, and 15 ft. 5 in. long. The furnace extended the whole width of the boiler, its flat crown-sheet being stayed to the shell by "crow-foot" braces.

In September, under hydrostatic pressure on the wharf, a brace broke in the crown-sheet at 42 lbs., and at 60 lbs. pressure 12 had given way. After being repaired, it bore 59 lbs. per sq. in. in its position at Sandy Hook without fracture, and was after subjected to a steam pressure of 45 lbs.

Steam being raised on this boiler, on the 23d inst., at 50 lbs. pressure, a loud report indicated the breaking of braces, and at 53½ lbs., the water standing at a height of 15 in. above the tubes, a tremendous explosion tore the boiler completely to pieces, throwing some of its parts several hundred feet.

The result of the first experiment had a tendency to confirm many of the party present, in the singularly general belief that explosions never occur except when the boiler has an insufficient supply of water, but the second experiment was a severe blow, and the last completely dissipated any remaining prejudice of that nature, and it is proven, beyond the possibility of a doubt, that a most destructive explosion may be possible with plenty of water and at a moderate pressure. Probably very few of our expert and scientific engineers required to be taught the fact in this decisive manner, but the belief referred to is so general among engine drivers and others who are most nearly concerned in the matter, that we cannot doubt that we are indebted to Mr. Francis B. Stevens, for the preservation in the future of many lives and an incalculable amount of property.

These experiments will be continued until the nine boilers now referred to are all destroyed; and, at the close of the work, a carefully prepared and exhaustive account will be made public.

It is certainly the duty of every steamboat and railroad company to consult their own interests as well as those of the public, and to assist in this work either by placing in the hands of Mr. Stevens large additions to the fund established by the united R. R. companies, or by conducting independent experiments, and it is to be hoped that the General Government will also lend pecuniary assistance in this truly humane enterprise.

PNEUMATIC DESPATCH TUBES—THE CIRCUIT SYSTEM.*

From "The Engineer."

The author commenced by remarking that, soon after the introduction of the electric telegraph, it was found necessary, in large towns, to establish branch telegraph stations, at which messages could be collected for, and to which messages could be sent from, the central station. Both telegraph wires and messengers were tried for the purpose of keeping up communication between the central and branch stations; but neither of these means was found perfectly satisfactory, as the messengers proved too slow, and re-telegraphing the messages added another chance to their being mutilated in transmission. Under these circumstances, the Electrical and International Telegraph Co. connected their central station in Telegraph street, and their nearest branch stations in the city, by means of pneumatic tubes, through which carriers, containing messages, were forced in one direction by compressed air, and in the other by the air of the atmosphere flowing through the tubes into an exhausted re-

* A paper read before the Institution of Civil Engineers, by Carl Siemens, C. E.

ceiver. This system of tubes, which was designed and carried out by Mr. Latimer Clark, M. Inst. C. E., and Mr. Varley, M. Inst. C. E., was still in existence, and had indeed been considerably extended since the telegraphs had passed into the hands of the post-office authorities. It was worked by means of air-pumps, actuated by steam engines placed in the basement of the central station. This system had comparatively a very limited power of despatching messages, except for short lengths, as it was necessary to wait till a carrier had completed the whole of its journey in one direction before another could be sent in the other direction, and it did not admit of intermediate stations being inserted, but every two stations must be connected by means of a separate tube.

In April, 1863, the Prussian Government applied to Messrs. Siemens and Halske, of Berlin, to propose a system of pneumatic tubes for that city. After making numerous experiments, that firm proposed laying tubes, arranged in a circuit, to be traversed by a continuous current of air always kept flowing in the same direction. The peculiarities of this system, namely, the continuous current of air and the power of putting carriers into the tubes at any point, gave it great superiority over previous systems in the amount of work it was capable of doing. The Central Telegraph Station and the Exchange at Berlin were connected together, on Messrs. Siemens and Halske's system, in 1865, by means of two parallel lines of drawn wrought-iron tubing, 2 1-2 in. internal diameter, one tube being used exclusively for the passage of carriers in one direction, and the other for carriers going in the opposite direction. The continuous current of air was produced by means of a steam engine, working a double-acting air-pump, in the basement of the Telegraph Station. After the first line had been in use in Berlin for a year and a-half, and had proved perfectly satisfactory, the Prussian Government ordered an extension from the Telegraph Station to the Potsdamer Thor, with an intermediate station at the Brandenburger Thor, and expressed the intention of providing the whole of Berlin at a future time with a network of pneumatic tubes. The total length of the pneumatic lines laid in Berlin was 32,000 ft., including the first experimental line of 5,670 ft. On account of the great length of the second circuit of tubes they were made 3 in. in diameter inside, and this dimension would be adhered to in future extensions.

There was also a circular pneumatic system in Paris, but the continuous current of air was not used. Messrs. Siemens and Halske recommended their plan to the French Government before the Berlin line was constructed; but the French Government preferred a modified arrangement of their own. Each station on the French line was provided with large air-tight vessels, which were in communication with the water mains of the town. By admitting water under a considerable pressure the air in the vessels could be compressed to about two-thirds of its volume, and by means of the air so compressed the carrier, or train of carriers, was driven to the next station, from whence it was again driven to a further station, by the air which had been compressed in another set of vessels, and so on, from one station to another, at stated times, round the circuit. The author observed that the consumption of water by this system must be enormous, because, as the air was compressed to two-thirds of its ordinary volume, for every volume of air used the expenditure of a volume and a-half of water was required. The French line was circular, in so far as it started from the Central Telegraph Station, and passed through four stations, namely, at the Madeleine, the Grand Hotel, the Bourse, and Post-office, and returned to the Central Telegraph Station; so that the carriers were always sent through the tubes in the same direction. The working powers of this system were of course very limited.

In London there was another pneumatic line which should be mentioned, although not designed for the conveyance of telegrams or single letters, but of large parcels; namely, the large cast-iron tube, of a D section, running from Euston Station, *via* Holborn, to the General Post-office.*

Five or six years ago, Messrs. Siemens Brothers tried to induce the Post-office authorities to adopt their system of pneumatic tubes for the conveyance of

* Fuller information with respect to this line will be found in a paper read before the British Association, in 1870, by Robert Sabine, Assoc. Inst. C. E. *Vide* "Engineering," Sept. 23, 1870.

letters in London ; but it was only in December, 1869, when the telegraph lines were being taken over by the Government, that they received an order to lay an experimental circuit between the Central Telegraph Station and the General Post-office in St. Martin's-le-Grand. This line was completed and opened for traffic in February, 1870, and, after half a year's work, the great advantages of the system having shown themselves, a further length to Fleet street, and subsequently to the West Strand office at Charing Cross, was decided upon. The different stations were connected by two lines of wrought-iron tubing, having an internal diameter of 3 in.; both lines were laid in the same trench, at a depth of about 12 in. below the pavement, and parallel to one another. The tubes forming the circuit were of an average length of 18 ft. 8 in. For turning round street corners, and for rising and falling in the different buildings, pieces bent to a radius of 12 ft. were used. The ends of every two consecutive tubes were brought close together, and joined by means of a cast-iron "double collar," similar to those used for joining cast-iron water pipes, but having in the centre of its length an annular projection 2 in. wide, which was bored out just to fit over the ends of the tubes to make them butt true. A common lead and yarn joint was made at each end of the collar. Water-traps, communicating by means of slots with the bottom of the tubes, were placed at depressions on the line, to enable water, which might have got into the tubes through condensation or otherwise, as well as dust, or foreign matter, to be drawn off, without its being necessary to take up any of the tubes. A current of air was constantly circulating through the tubes, by means of a steam engine and double-acting air pump, supplied by Messrs. Eastons, Amos, and Anderson, placed in the basement of the Central Telegraph Station. Each station on the circuit had two sending and receiving instruments, one on the top and another on the down line of tubes. The instruments consisted of two short tubes, fixed side by side in a rocking frame, each of which could be brought into line with the circuit of tubes, at the pleasure of the attendant. Each end of the rocking frame was faced, and worked against the faced side of a boss, into the centre of which was fixed a piece of wrought-iron tube, forming part of the circuit. Three annular grooves were turned in the faced side of the boss round the tube forming the end of the circuit. The use of these grooves was to prevent the escape of air between the ends of the rocking frame and the bosses at either side of the apparatus. One of the tubes in the rocking frame, that called the sending or "through" tube, was simply a hollow cylinder, of the same internal diameter as the tubes forming the circuit. When this tube was in line with the main tubes a carrier could pass through the instrument without being stopped, and this tube was used when it was desired to put carriers into the circuit. The other, or receiving tube, had a perforated diaphragm at its "down stream" end, so as to arrest the carriers when it was placed in line with the main tubes of the circuit. This tube was D-shaped in section, with a flat cover, which could be taken off if required; as, for instance, to remove carriers, should two arrive at once, and so prevent the rocking frame being moved. The flat cover of the receiving tube was furnished with a pane of glass, to enable the attendant to see when a carrier had arrived. To prevent the continuous flow of air in the whole system of tubes from being impeded, should the receiving tube be left in circuit after it had caught a carrier, there was a by pass, which communicated with the tubes of the circuit on both sides of the instrument. A sliding rod, held on suitable supports, was supplied for pushing the carriers out of the receiving tube when intercepted and brought out of the circuit. The manipulation for sending and receiving carriers was exceedingly simple, and a treadle was provided to enable the attendant to move the rocking frame with his foot. The carriers for the reception of telegrams, letters, etc., consisted of small cylinders made of gutta-percha, papier maché, or tin, covered with felt, drugget, or leather. It was found in practice that the carriers need not fit the tubes at all accurately. Mr. Cullie, M. Inst. C. E., chief engineer of the post-office telegraphs, had adopted the block system, such as was used on railways, for working the tubes, and he employed instruments introduced by Mr. Tyer, Assoc. Inst. C. E., for making the signals. The use of the block system pre-

vented the tubes being able to develop their full working powers, which would be obtained by sending carriers one after another at half-minute or shorter intervals—a mode of working that could be easily carried out with a constant current of air, as was the case when the circular system was worked independently of other systems, which was not yet the practice in the metropolis. The total length of line now working in London, from Telegraph street to the West Strand Office and back, was 6,890 yards, as follows: From the instrument room on the third floor of the Central Telegraph Station to the General Post-office, 852 yards; from the General Post-office to the Fleet street street office, 1,206 yards; and from the Fleet street office to the West Strand office, near Charing Cross, 1,387 yards.

The following results as to speed were obtained during experiments made with the two sections first opened. The mean pressure during those experiments was 7 lbs. per sq. in. at one end of the circuit, and the vacuum at the other end of the circuit was 11 in. of mercury; under these conditions, the circuit being worked with both pressure and vacuum, the times were:

	Yds.	m.	s.
Telegraph street to General Post-office..	852	1	54
General Post-office to Temple Bar.....	1,206	2	28
Temple Bar to General Post-office....	1,206	2	10
General Post-office to Telegraph street.	852	1	13
	4,116	7	45

These experiments proved that the speed of the carrier was much greater as it approached the vacuum end of the tube than it was at the other end.

The necessity of having a steam engine with air-pumps and reservoirs was a great hindrance to the general introduction of pneumatic tubes; but this inconvenience had been successfully removed by the construction of an exhausting apparatus, working by the direct action of steam upon a current of air. In this exhausting apparatus the steam from a boiler was made to issue, in the form of a hollow cylinder, from an annular nozzle placed in the centre of the apparatus, the opening having a width of about one millimetre all round. The steam issuing in this form had the greatest possible surface, both inside and out, for contact with the air in the apparatus, which air was in connection with, and was drawn from, the pneumatic tubes. With one of these exhausters a vacuum equal to a column of 23 in. of mercury was obtained, with a less expenditure of steam than would be required to work a steam engine and pump to effect the same object. The principal recommendation of the steam exhauster, besides its extreme simplicity and the small space it occupied, was its cheapness of construction, as the cost only amounted to about one-twentieth part of an engine and pumps.

Where so large a traffic was not expected as in London, the tubes, instead of being laid side by side in the same trench, could, at a trifling additional cost, be laid in a large circuit, and so be made to include many more intermediate stations, each station in that case having only one sending and receiving instrument.

Experiments made at Berlin prove that, in very long lines of tubes of small diameter, a sufficient velocity of the column of air could be obtained with the pressure of the two ends differing within quite practical limits. If the carrier was made so as to move with very little friction, its speed would be nearly equal to that of the air by itself. The momentum of the carrier and that of the column of air might be entirely disregarded, as both were infinitely small when compared with the prevailing friction of the air in the tube. As under equal conditions of pressure at the two ends the speed in the tube increased as the square root of the diameter, and decreased as the square root of the length of the tube, the length of a pneumatic system might be extended with similar results as to speed, in the same proportion as the diameter of the tubes could be increased; that is, the same speed as was obtained through a tube of a certain diameter and length, might be obtained through another of double the length and double the diameter, the difference of the pressures at the two ends of the tubes remaining identical.

Up to the present time, as far as the public was concerned, the pneumatic tubes in London, Berlin, and Paris, had only been used for the conveyance of telegraphic messages; but the British Post-office authorities had already considered the question, whether it would not be advantageous to have the letter-post service in London executed by means of pneumatic tubes. With such a system of distribution an accumulation of letters at principal offices would be entirely avoided.

CANADIAN PETROLEUM.

From "Engineering."

During the last 20 years rapid advances have been made in the development of mineral oils, and their growing importance for illuminating and various other purposes gives them a high commercial value. The natural oils which flow from the earth were familiar to the ancient inhabitants of the world, both civilized and barbarous. Thus Herodotus, who wrote 440 years B.C., mentions a place called Arderrica, 35 miles from Susa, where there were wells yielding bitumen, salt and oil. The products of these wells were drawn off in utensils formed of wineskins cut in halves, and were allowed to settle in tanks. Here the bitumen and salt settled and hardened, the oil being drawn off into casks. This oil was known to the Persians as "Rhadinace;" it was black and had an unpleasant odor. The Persians, Burmese, and other nations still continue to employ these substances in their crude state to give light, and for medicinal purposes. In 1694 we have it recorded that Messrs Eeely, Hancock, and Portlock obtained a patent for making "pitch, tar, and oyle out of a kind of stone." In 1761 oils were distilled from black bituminous shale, and were used medicinally, as stated in "Lewis's Materia Medica" for that year. More than a century ago oils were obtained by the distillation of coals, but the purification of those oils and their application to the common requirements of life have progressed but slowly, and have hardly yet reached perfection.

The first successful attempt to manufacture oils from coals in America was made by Dr. A. Gesner, who made and consumed this oil in lamps in 1846. His inventions are known as the kerosene patents, and were purchased by a company, and worked in the production of kerosene oil. Although great advances have been made in this class of apparatus, it can hardly yet be said to be so perfect as to meet the general approval of manufacturers. When once started, the production of oils from bituminous substances extended very rapidly to the chief cities of the Atlantic seaboard, as well as to those of the coal districts of the interior. The great cheapness of the oil obtained by the distillation of petroleum has, however, almost caused the coal distillation to be suspended. It will probably only be resumed when the petroleum wells cease to yield sufficient oil for the various purposes to which it is now applied. Ten years since, a calculation was made which showed that whenever crude petroleum reached an average price of 35 cents per gallon in the American markets, the coal distiller could afford to resume business.

But although at the present time there is an abundant yield of petroleum, there is an enormous amount of waste going on in the process of rendering it commercially useful. In the Dominion of Canada—to the oil wells of which we now more particularly refer—this waste arises from the present imperfect methods of manufacture, and reaches the enormous amount of 40 per cent. of the crude oil. It is estimated that the surplus crude oil of the Dominion now unsalable, reaches 350,000 barrels per annum. Besides the waste resulting from the present modes of manufacture, the finished oils produced in Canada possess a very offensive odor, owing to the presence of sulphur and arsenic in the crude oil. This has been neutralized by chemical means, but only temporarily, as the odor invariably returns, the results of the treatment not being permanent. The United States crude oil is much purer, and consequently sells at a higher price.

The great waste to which Canadian oil is subject is, however, likely to be checked, and the 40 per cent. of residuum of the ordinary makers to be profitably utilized. This anticipated saving will be effected by an improved distilling apparatus which has been invented by Messrs. Houghton and Howell, of St. Catherine's, Ontario. By means of this apparatus the waste of other makers is not only utilized, but the most valuable products are obtained therefrom. From this waste material a lubricating oil of very high quality is produced. From long trials of this oil, it is affirmed that it is not decomposed nor dried up in steam cylinders; that it is not injurious to iron; and that it will not oxidize. It, moreover, produces no acid reaction, remains perfectly limpid at 2 deg. below zero, and is not explosive nor inflammable. By the new process the arsenic and sulphur are

entirely removed from the carbon oils, which are perfectly and permanently deodorized. But beyond the deodorization and conversion of the waste of other makers, Messrs. Houghton and Howell utilize the crude oil to the greatest possible extent. The largest amount obtained by other Canadian refiners from the crude is 60 per cent., and their products are then very inferior. By the patent still and machinery a yield of from 90 to 95 per cent. is obtained, whilst at the same time both the illuminating and lubricating oils possess a greater money value than do those obtained by the old mode of distillation.

The new process has been carried out in the Dominion for some little time past on a moderate scale, with success; but, being capable of wide extension, additional works are now being constructed by an English company. These works are being erected at Port Sarnia, situated upon the River St. Clair, which connects the lake of that name with Lake Huron. They are about 14 miles from the great cluster of oil wells in Petrolia, and are situated on 23 acres of land, with an extensive river frontage. There is railway communication direct between the oil wells and the works, and competing lines between the works and other parts, besides which there is navigable water available for six months of the year, thus affording direct communication with all parts of the world. The machinery for these works has been supplied by an English engineering firm, who are now superintending its erection.

We have said that the new process has been in operation for some time past, and we may here add that the products are highly appreciated in the Ontario district, where they have been largely used. The efficiency of the lubricating oil was fully proved by Mr. C. Stovin, the general manager of the Welland Railway in Canada, and who, it will be remembered, was formerly traffic manager on the London and South-Western Railway. In the beginning of the present year Mr. Stovin had the oil put to a severe test on his line. The mail car came out of the shops with new brasses fitting tightly. The wheels on one side were packed with the new oil, and those on the other side with the oil in ordinary use on the line. The journals packed with the new oil worked themselves into their proper bearings without once heating. The car ran for 13 days without a fresh supply of the lubricant, the boxes not being touched during that time. The journals on the other side heated badly, and had to be oiled every morning, and some times a mid-day dressing was found to be necessary. A trial of the oil on a locomotive engine was most satisfactory; it was carried on during very severe weather, even for Canada, and when no other oil would remain upon the machinery. The oil has also been used in England by several engineering firms with success, and bids fair to take its place as a valuable lubricant for machinery, and for railway axles. For the latter purpose especially, there is a good opening for a really efficient lubricant.

THE SEC-SYSTEM OF NOTATION.

From "The Mechanics' Magazine."

The present mode of counting by tens appears to have become so firmly established among us, that it would actually astonish some people to hear of so monstrous a thing as a change being even contemplated. Yet it is undeniably true, as Dr. Lehmann recently stated at Leipzig, that 10 is occasionally an awkward figure to deal with, and that common sense and sheer necessity have at times driven us to adopt another basis for calculation, although few have ventured to go as far as to prepare an entire reform of our numerical system. Klugel, however, mentions a case in point. Anno 1800, Herr Werneberg, the author of "Teliosadik," has laid it down as the duty of every honest man and every sensible and well-established Government to introduce, and, if necessary, to force upon the nations the dodecaic or duodecimal system. The fault found with 10 is that it is not divisible by 3 and 4, and that its divisibility by 5 is no adequate compensation for that deficiency.

Take the number 12, for instance, and it is at once apparent what facilities are afforded in its sub-division. There is the

$\frac{1}{2}$, the $\frac{1}{3}$, the $\frac{1}{4}$, and the $\frac{1}{5}$, all in round numbers, and, if 12 instead of 10 were made the basis of our numerical system, these advantages would become still more striking. The introduction of this basis would involve but few changes. New digits would have to be invented in the place of 10 and 11, and 12 would have to be written 10. It will be readily observed that the change is not beyond the realms of even practical possibility, and that the difficulties are far from being insurmountable. In fact, there are precedents in most civilized countries which would help in making the matter more familiar. The dozen, for instance, is a well-known quantity everywhere, and one which is used in more cases than in that of the number of pence making a shilling or the *Pfennige* making a *Silbergroschen*. Moreover, the words brace, stone, score, etc., remind us that the decimal system is not altogether universal. But to look at our familiar 100, and to fancy it to mean 12 dozen, is more than many of us can muster courage enough to endure, even those perhaps who without any compunction look upon a hundredweight as something different from 100 lbs.

Our numerical notation is, after all, but an acquired habit—the mode of counting which we are used to and inured in; and the elasticity of mind which would be required in order to change it for a better one, would probably be as much wanting in this as in several other quite as plausible cases of reform—the phonetic alphabet, to wit. The thing is said to look quite as well as things do occasionally in a picture, but pretty looks and practicability belong to two different spheres.

Dr. Lehmann's proposition, however, is not to introduce 12 as a basis, but 6; and in order to be better able to follow his arguments, it will be well to familiarize the matter by keeping in mind that he means to count and reckon with half-dozens instead of tens. Thus, in speaking of 80 at present, we mean 8 tens; but we might think of that figure as implying 8 dozens, or 8 half-dozens, as the case may be, the only difference being that we are used to parcel a figure out into so many tens, etc., instead of parcelling into dozens or half-dozens, etc.

It must be remarked at the outset that Dr. Lehmann reopens rather than introduces a question on the system of figures. It is stated by Libri that in the "Nouveau Traité de Diplomatique" (Paris, 1750, p. 513), mention is made of a sign for 6 which, by adding unity, expressed the subsequent figures. Peyron goes farther back than this. He states that in the Chapter-Archiv of Vercelli, this same sign for 6 is to be found on a MS. of the 9th century. If at the present day 6 were introduced as the basis of our notation, we should write it 10, and the reason why this was not done in the case of the sign just alluded to, is evidenced from the fact that the cipher 0 was not known in Christian Europe before the 13th century.

In order to facilitate the introduction of the new basis, and to avoid confusion, Dr. Lehmann proposes to change the name *sechs* into *seh*, and for argument's sake let us say that our word six be changed similarly into sec, so that we should have to count one, two, three, four, five, sec. The higher figures might be called twosec, threesec, foursec, fivesec, secsec, or sess, in accordance with the author's proposition. This latter figure would be equivalent to 36, but it would be written 1 and 2 noughts.

It is farther proposed to change the type so as to suit the new system. There would only be wanted 5 digits besides the 0, and Dr. Lehmann uses for the even figures digits with round heads, and for the odd ones digits with sharp heads. They might, for the sake of illustration, be formed out of ordinary 0, 2, 4 and 1, 3, 5, type by mutilation.

This innovation appears somewhat arbitrary, seeing that a change in the 1 would do all that is necessary.

The advantages derived from the adoption of this system are by no means imaginary. The unschooled laborer, and the village urchin, tortured alike by severe computations as high as 5×7 or 8×9, will hail the day, with ecstasy which shall abolish them, and many a schoolboy will leap with joy as he hears of the advent of tables not a quarter as big as those which he now has to master in order to make his sums come without dodging.

The following shows the extent of the tables under the sec-system. In making use of the ordinary type, it must be borne in mind that 10 is equivalent to 6:

$2\times2=4$	$3\times2=10$	$4\times2=12$	$5\times2=14$
$2\times3=10$	$3\times3=13$	$4\times3=20$	$5\times3=23$
$2\times4=12$	$3\times4=20$	$4\times4=24$	$5\times4=32$
$2\times5=12$	$3\times5=23$	$4\times5=32$	$5\times5=41$

It is undeniable that the easier mode of multiplication and division resulting from the use of this system affords a guarantee for the decrease of errors in arithmetical calculations. It might, however, be argued that the length of figures will be increased in proportion with the smallness of the base; and this is true, although the inconvenience seems hardly of much account, when it is considered that up to 7775 one, and up to 60,466,175 two, additional digits only would appear under the sec-system.

In addition or subtraction, the figures to be retained or carried are limited to 4, and there are other facilities which are not altogether unworthy of notice. In counting money, *f. i.*, it is customary to take up by threes, since that number is easiest to overlook. This, however, entails the taking up of 1 in every 10, which under the sec-system is not necessary.

If, says Dr. Lehmann, the practicability of the sec-system can hardly be questioned, it is nevertheless to be feared that the way to its introduction will be barred by considerable difficulties. They are, however, by no means insurmountable. A beginning ought to be made in schools, and commerce and finance would in time have to follow suit. A Government interference on behalf of the system would also be desirable, and if one nation had fairly adopted it, the others would soon do likewise. The pains and penalties, however, attached to the labor of forcing this innovation into its proper place, would be amply rewarded by the satisfaction derived from the conviction of having delivered the coming generations from the trammels and difficulties attached to the calculations under the present decimal system.

HEAVY AND LIGHT ARTILLERY.

From "Engineering."

The satisfactory results of the firing of the 35-ton gun since its enlargement have so enchanted the Government, that we hear it is contemplated to enlarge the calibre still further. Not content with burning all the powder, obtaining low pressures and high velocities, the authorities appear to be desirous of going a step further. With what object it is hard to say, but with what result it is easy to predict, namely, the probable destruction of the gun. If, as we recently pointed out, the enlargement of the bore of the gun from 11.6 in. to 12 in. involves, as it does, a corresponding shortening of the 700 lb. projectile; which will lead to unsteadiness in flight, greater air resistance, and a reduction of penetrative power, what must the further increase in calibre enlargement do? We certainly consider the gun as already sufficiently spoiled for all purposes of correct shooting, without further experiments being tried on it in the direction of enlargement. For our own part we cannot conceive why the gun was not sent to be tried at Shoeburyness for range and accuracy before it was enlarged at all. The Committee on Explosives are well aware that when its calibre was 11.6 in. they obtained pressures of 21.7 tons per sq. in. on the projectile, 20 tons per sq. in. at the vent, and 1,353 ft. initial velocity per sec., with 120 lbs. of pebble powder. They must also know that they have not been able to obtain less than 25 ton pressures, nor more than 1,355 ft. velocities from 115 lb. charges with the gun since its enlargement. The contemplated alteration will further remove the possibility of ever rendering it a useful weapon. We hope, however, that better counsels will prevail, and that the gun will at once be sent to Shoeburyness for trial at the targets, in order to decide how far its shooting has been impaired already. The officials at the Royal gun factories are desirous that it shall be sent there, as they wish to proceed with the manufacture of the other 35-ton guns now arrested in various stages of progress pending the decision of the committee as to the most suitable calibre. We hope the committee will pause ere they again send the gun to the boring mills, for they ought to know that low pressures and high velocities at Woolwich may possibly mean want of accuracy and low penetrative power at Shoeburyness.

The 10 in. gun with which the committee are experimenting at the proof butts, Woolwich Arsenal, was recently fired with 70 lbs. of powder and a 1,000 lb. projectile.

This bolt was fitted with studs to take into the rifling of the gun, and when this piece was loaded the shot projected beyond the muzzle. Notwithstanding its great length it preserved its balance on its longer axis, and buried itself point foremost in the butt. It cut holes through the velocity screens as clean as round shot would have made. In all respects the gun came well out of this ordeal; the committee, however, have further trials in store for it.

Turning to guns of a lighter class, we have first to notice some satisfactory trials which have recently been made at Shoeburyness with the 16-pounder muzzle-loading rifled field gun. These guns weigh 12 cwt., and are rifled in 3 shallow grooves similarly to the 9-pounders. The shape, however, differs from that of the latter, there being no swell at the muzzle. The sighting is also different, occupying a central position on each of the trunnions. There also is a clever arrangement for securing the screw which tightens the rear sight. In lieu of the old chain which frequently became detached, there is an arm upon the head of the screw which catches against a button on the surface of the breech as it unwinds itself, and prevents the screw from making more revolutions than are actually requisite. The carriages, limbers, and ammunition wagons for these guns have also been improved in detail. In the recent experiments the gun charges were 3 lbs. of R. L. G. powder, and the projectiles in the first series were common shells with Royal Laboratory screw percussion fuzes, the range being 2,500 yards. Four rows of targets were set up 20 yards apart, each row being 54 ft. long, and 9 ft. high. Out of 10 rounds fired 1 was blind, the 9 giving as a result per shot on the four targets (which were placed to the rear of each other) 7.0 throughs, 2.1 lodges, and 0.9 strikes. In the second series shrapnel shells with R. L. screw percussion fuzes were fired with 3 lb. gun charges. Ten rounds were fired; one shell burst beyond the targets, and the remaining 9 gave per shot 23.4 throughs, 12.1 lodges, and 4.0 strikes. The 3d series consisted of 10 rounds with shrapnel shells, having wood time fuzes, and fired with 3 lb. powder charges as before. Two rounds proved blind, the 8 effective shots giving 36.6 throughs, 9.9 lodges, and 20.0 strikes per round. These results speak well for the range, power, and accuracy of the new 16-pounder gun, which has yet to undergo further trials at still greater ranges.

We have next to notice a new gun of a class, the introduction of which into the service has been contemplated for some time past. This is a powerful rifled howitzer, the example at Shoeburyness—the first of its kind—weighing 46 cwt., and having a bore of 8 in. diameter, with an uniform rifling of 1 turn in 16 calibres. It is mounted on a wrought-iron carriage weighing 27¼ cwt., and fitted with removable wheels, the gun being worked from a wood ground platform. This gun so far has been tried for range and accuracy of fire with common shells weighted to 180 lbs., and plugged. In the first of the two series of experiments 29 rounds were fired with charges varying from 1 lb. to 8 lbs. of R. L. G. powder. The mean ranges obtained were from 491 yards, with 1 lb. charges to 4,328 yards with 8 lb. charges. In the second series 18 rounds were fired with 8 lb. powder charges at an elevation of 40 deg. 5 min. recoil checked, the mean range being 4,283 yards, and the mean time of flight 27.0 sec. Two rounds with 10 lbs. of powder, at the same elevation as before with the recoil checked, gave as a result: mean time of flight 30.1 sec., and mean range 5,134 yards. The accuracy of the gun was fully equal to what could be expected from firing under the conditions of the above experiments.

CURVES IN WAGON ROADS.

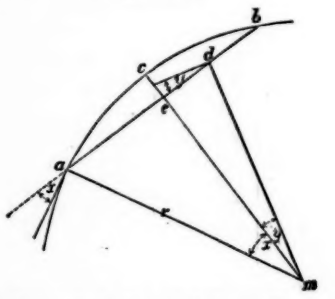
By DÖHNERT.

Translated from "Der Civil Ingenieur."

It often happens that the road engineer has to decide whether a curved street is sufficient for the carrying of long beams in respect to length of radius and width. Mere practical experience seems not to suffice in disputed cases. The familiar formula $r = \frac{l^2}{2b}$, (in which r = radius, l = length of wagon, b = width of road), does not give a satisfactory solution when

tested. For example, suppose $l = 30$ metres, $b = 6$ m., $r = \frac{30.30}{2.6} = 75$ metres; while for the same length with a breadth of 9 metres $r = \frac{30\ 30}{2.9} = 50$ metres. These dimensions, as road-builders know, are much too large, for wagons of such lengths turn much sharper curves. The explanation lies in the fact that no attention has been given to the fact that the rear axle under a long beam swerves or sheers from the curve in a peculiar way.

The departure or sheering of the hind axle is a peculiarity of transport of long beams which the writer has investigated, with the following results.



If a beam is to be carried exactly round a curve (reach between axles not being taken into account), the extremities must move in the same arc of a circle. Let $a\ b$ be the beam, and $a\ c\ b$ the arc with centre m. The forward axle is at a, the other at d, and for long beams generally $b\ d = \frac{1}{4}\ a\ b$. Now, if the ends move in a circle about m, all other points of the beam, as d, must do the same. Hence the motion of d is always in the direction of the tangent; the same is true for a. Hence both the forward and the rear axles have a tangential direction, and the length from thill-pin to the forward end can be left out of account, for the direction of the thill varies little from that of the tangent.

We see then, that for given length of beam and given radius the position of the axles can be exactly determined. The angle of deviation according to simple geometrical principles is shown at the centre m, and it is $x = x$, $y = y$. But

$$\text{Tan } x = \frac{a\ e}{e\ m} \quad \therefore e\ m = \frac{a\ e}{\tan x}$$

$$\text{Tan } y = \frac{e\ d}{e\ m} \quad \therefore e\ m = \frac{e\ d}{\tan y}$$

Hence

$$\text{Tan } y = \frac{e\ d}{a\ e} \tan x.$$

But

$$e\ d = \tfrac{1}{2}\ a\ e.$$

$$\therefore \text{Tan } y = \tfrac{1}{2} \tan x.$$

The angle x and y therefore have a constant ratio independent of width of road and length of beam; that is, the tangent of the rear angle is half as large as the tangent of forward angle. Generally the latter is not more than 30°, and the mean may be taken at 22°. Now

$$\tan 22° = 0.4040; \quad \therefore \tan y = 0.2020,$$

so that $y = 11°\ 15'$, a little more than a half of 22°. The smaller x is the nearer y approaches the exact half of x.

This ratio holds if the beam is carried so that both ends move in the arc of a circle. But it generally happens that the two tangential angles differ, so that the various points of the beam deviate from the forward angle. Hence it is better to assume a mean angle smaller than the extreme angle of deviation, which in most cases is about 30°.

It is obvious that the angle x of the forward axle is of importance with reference to the length of the beam. The larger this angle the longer the beam may be, and conversely. To determine the relation:

$$\text{Sin } x = \frac{a\ e}{a\ m}$$

$$\text{Since } a\ e = \tfrac{1}{2}\ l \text{ and } a\ m = r.$$

$$\text{Sin } x = \tfrac{1}{2}\ \frac{l}{r}$$

$$\therefore r = \frac{l}{2 \text{ Sin } x}.$$

Suppose $x = 30°$ (the maximum)

$$r = \frac{l}{2 \text{ Sin } 30°} = \frac{l}{2}, \text{ since Sin } 30° = \tfrac{1}{2},$$

i. e. the shortest permissible radius is equal to the length of the beam.

As above stated, the angle x must be taken less than 30°. For 22°

$$r = \frac{1}{2 \text{ Sin } 22°} = \frac{1}{2\ (0.3746)} = \frac{4}{3}\ l.$$

The radius should, therefore, generally be $\frac{1}{3}$ longer than the beam, and can be shorter only in exceptional cases.

The formula shows that the radius is entirely independent of the width of roadway. Still a certain width is of course required. In what ratio this stands to radius and beam length shall be investigated hereafter.

With regard to the rear deviation,

angle ; suppose that the tail-end is not $\frac{1}{4}$, but $\frac{1}{3}$ of the entire length, *i. e.*

$$b = y\tfrac{1}{3}\, a\, b.$$

Then

$$\text{Tan } y = \tfrac{1}{3} \text{ Tan } x.$$

$$\text{Sin } x = \tfrac{1}{2}\frac{l}{r}.$$

$$r = \frac{l}{2 \text{ Sin } x}.$$

Hence this equation holds for long or short tail-end, and for y large or small; in other words, the radius of the curve is the same whether the hind axle is set at $\frac{1}{3}$ or $\frac{1}{4}$ of the beam-length. This also holds if the axle is at the middle point e; for then $y = 0$; *i. e.*, the deviation becomes zero. Now suppose the axle at e and that the beam is of the length $a\,d = \frac{2}{3}\, l_1$; then $e\,d = \frac{1}{4}\, a\,d$. But $a\,d = \frac{2}{3}\, a\,b$, or $l_1 = l$. When $x = 30°$, we found $l = r$. Substituting,

$$r = \tfrac{2}{3}\, l_1;$$

i. e., the radius should be at least $1\frac{1}{2}$ times longer than the beam to prevent sheering.

Taking the forward angle at 22°

$$l = \tfrac{3}{4}\, r.$$

$$\therefore\ l_1 = \tfrac{2}{3} \cdot \tfrac{3}{4}\, r = \tfrac{1}{2}\, r.$$

Therefore, in general the radius must be twice as long as the beam. This will also apply to other carriages which have fixed hind axles. The racks of hay wagons measure at most 7 metres, so that the radius of the curve should be 14 metres. Such a curve would answer for an ordinary carriage road.

With reference to the width of roadway: suppose $l\ n$ to be the beam, with ends moving in an arc $l\,m\,n$, then the versine $m\ e$ of this arc is the required width. For (o being the centre of the arc)

$$\overline{l\,o}^2 = \overline{l\,e}^2 + \overline{o\,e}^2.$$

But

$$l\,o = r;\ l\,e = \frac{l}{2};\ e\,o = r - z.$$

$$\therefore\ r^2 = \left(\frac{l}{2}\right)^2 + (r-z)^2,$$

hence

$$z = r - \sqrt{r^2 - \left(\frac{l}{2}\right)^2}.$$

This value suffices, if the beam moves exactly as supposed. As this is in practice impossible, an excess must be allowed for play, which may be done by multiplying the value of z by some number greater than 1; for the above conditions this may be $\frac{3}{2}$. But another condition must be introduced. So far the carriage and load have been considered as a line, but as they have a necessary width, allowance must be made for this. It will be safe to increase the last value of z by a constant equal to the width of carriage, say 2.5 metres.

Hence, finally,

$$z = a\left\{ r - \sqrt{r^2 - \frac{l^2}{4}} \right\} + 2.5.$$

Calculating for several beam lengths and radii (the beam never being longer than radius) by the last formula we get the following table. (Dimensions in metres.)

Mean Radius.	Width for a beam-length of					
	15.	20.	25.	30.	35.	40.
15	5.5	..	..	.	..	..
20	4 7	6.5	..	..	..	..
25	4.2	5.6	7.5	..	..	..
30	3.9	5 1	6.6	8.5	..	..
40	3 6	4.4	5 5	6.9	8.6	10 5
50	3.3	4 0	4 9	6.0	7 2	8 8
60	3.2	3.8	4.5	5.4	6.4	7 6
70	3.1	3.6	4.2	4 9	5.8	6 9
80	3.0	3.4	4.0	4.6	5.4	6 4

These dimensions have proved sufficient in actual experiments ; and for the extreme minimum permissible, may be taken at 1 metre less.

For a straight road, r is infinitely long; hence, by the formula, $z = 2.5$ metres.

If the curve is to allow for meeting and turning out, then the width must be at least 2.5 metres greater.

It has been supposed that the street is just broad enough to let the tail-end of the beam swing round. For the case in which the forward end can swing beyond the roadway, the calculation differs a little. In this case

$$\text{Sin } x = \frac{a\,e}{a\,m}.$$

But

$$a\,e = \tfrac{3}{4}\, l, \text{ and } a\,m = r.$$

$$\therefore\ \text{Sin } x = \tfrac{3}{4}\, l \cdot \frac{l}{r}$$

$$r = \tfrac{3}{4} \cdot \frac{l}{\text{Sin } x}.$$

For

$$x = 22°.$$

$$r = \tfrac{3}{4} \cdot \frac{l}{\text{Sin } 22°} = l.$$

But the width varies, since

$$c\,e = r - \sqrt{r^2 - (\tfrac{3}{4} l)^2} + 2.5.$$

CRITICAL EXAMINATION OF THE IDEAS OF INERTIA AND MOMENTUM.

By JAMES D. WHELPLEY.

10.—Doctrine of inertia as a measure of the quantity of matter.

In sections 2 and 6 I have expresed only a part of the entire theory of inertia. There is, indeed, no absolute inertia, which, by its sum of equal units, shall give always the total of force and quantity of matter; but there is a *proper* inertia of each mass, not given by induction from other matter, but determined by a similar induction in the mass itself through the reaction of its parts. This reaction is modified by the same laws of distance and quantity, internally, that regulate external influence. The reaction of a mass upon itself is definite and constant, as long as the density of the mass and the arrangement of its parts remain unchanged; nor does it vary under external influence; in this way constituting, in each mass, a constant base of force. In section 6 two bodies, A and B, are given, composed, A of 1, and B of 10 units of matter. In this example I did not speak of the *proper* inertia which belongs to each unit, and is independent of the external inductive forces; but it is this proper inertia, induced by the reaction of the molecular components of the mass upon each other, that furnishes a constant base for the derivation of the forces of relation; and if this is taken into the account it will be found that A, having the influence of the 10 units of B bearing upon it, has added to its proper inertia 10 units of induced inertias, making in all 11 dynamic elements. Its own inertia may exceed the sum of all the inductions.

But it is evident that we have no other standard for the quantity of matter in a mass, except its proper or sel-induced inertia, and the quantity of this effect will determine that of gravitation. *But if a mass of matter be broken or separated in few or many parts, the sums of the proper inertias of these parts will not be equal to that of the original mass.* This was not the opinion of Newton, who maintained that inertia was inherent in the ultimate atom, and not subject to variation through internal or external inductions. There is no question here, nor need be any, of molecules or atoms; it is not desirable to pass into the region of hypothesis while determining first principles.

11.—Theory of momentum.

The momentum of a body in motion is always, and at every instant of time, a definite sum of forces, which varies as the square of the velocity. A body moving freely, and consequently evolving motor force, has gained power by a sum of positive and negative increments from the point of rest. If, on the other hand, it is relatively at rest, it has arrived at that by a sum of positive and negative decrements. This principle is sustained by observation, since everything at relative rest can be shown to have been in motion. *Motion and rest are both positive and relative, and not relative alone.*—(Newton.)

Setting aside the directive influence of the sun, the momenta of the planets must be regarded as the result of a gradual acceleration and storing up of motor forces in their mass. They are in the condition of positive motion, irrespective of other bodies, and of relative motions, or rest, in regard to all other bodies.

It is necessary to bear in mind that each member of the solar group is itself an independent system, governed by the same laws that actuate the whole; and, if the earth were the only body in the molecular universe, it would still have a proper inertia, created by the reaction of its particles upon each other; and this inertia would have a definite value, although there might be no other body with which to compare and measure that value.

The motor value of the proper inertia of the earth is shown by the slow and slight movement with which it yields to the guiding influence of the sun; its movement during one second under solar pressure is said to be only .119 of an inch.

12.—Theory of induction.

By whatever means the sum of inertias of a body is increased, by the same its inductive power in evolving motor force, and the motion of gravity in other bodies, is augmented. For, I have shown that the initial value of a mass is the degree of force with which it holds its first position in space, and

that this mutual establishment of inertias is the primary effect of masses, and the components of masses, upon each other; while the motion of gravity (evolving motor force) is a secondary result of the formal inequalities of distance in the parts of bodies.

If two plummets are suspended at the surface of the sea, near to each other, their mutual attraction will vary with the degree of their terrestrial gravitation; and this, again, will vary with the solar distance.

Let three equal and homogeneous bodies be at unequal distances in space, and free to move; all other influences beside their mutual and self-gravitation being either null, or else equal and uniform. Each will affect the other inductively in the inverse ratios of their distances. Each of the three independent masses will have a proper and constant inertia, due to the interaction of its own particles. If this system of three bodies approaches the sun, the solar influence will be added to its proper inertias, and the mutual gravitations of the three will be intensified in the same proportion.

13.—LINEAR MOTION A FORM OF RECIPROCATION.

It appears to be impossible to discuss the continuous movements of bodies without resolving them into vibrations. I am obliged to assume the truth of this position, because I should not otherwise be in agreement with common experience.

But if, through any vibratory *molimen* of its molecular system, a body is being self-translated through space, this condition has been originated and induced by influences external to it. The movement of the solar system through space must have been slowly organized by the accumulation of minute impulses through periods of indefinite duration; for, there is no other mode, within our knowledge, by which such a result could be reached. A very small cosmical difference would be sufficient, since there is no limit in time for the accumulation of momenta.

All bodies, even balls of wet clay, or lead, are, in their interior nature, elastic. If it were not so, motion could not be communicated to them, either by gravity or by other cause.

Not only is molecular elasticity necessary to our common understanding of motion, but a body cannot even be brought to rest without illustrating all the laws of elasticity and of motor force. A mass lifted and laid upon a sustaining surface, changes its form by self-pressure in coming to rest; sensibly in large masses, as in a ship launched upon water; insensibly, but not less certainly, in smaller bodies. The "weight" of the mass, the primary motion evolved in it by the action of gravity, is finally balanced by the elastic cohesion of the molecules, and it comes to rest by means of a series of vibratory movements, in which the forces of inertia and cohesion are convertible or interchangeable.

14.—TERRESTRIAL INERTIA.

By the hypothesis of Newton, inertia is assumed to be an absolute endowment of matter, and the measure of its quantity. Gravitation, on the other hand, was taken by him to be a second force, the antagonist of inertia, and the effect of an unknown independent cause. I have assumed, on the contrary, that inertia is the primary effect of physical relation, and the motion of gravity a result of unequal inertias, due to the unequal distances of the parts of bodies.

Newton assumed that the proper inertia of a planet not only measured its quantity of matter, but was the unit and index of its gravitating force. It is necessary to acknowledge the truth of this assumption, since otherwise there would be no base of calculation for the masses of the planets. The proper inertia of the mass must be taken as a constant base.

In making this admission, I do not concede the absoluteness of the proper inertias of masses. I have shown, on the contrary, that the degree of inertia in a mass is not simply the sum of equal units composing it, but that it varies in a higher ratio than the number of units; that is to say, the reaction of the component parts is subject to the laws of distance, and the force itself is inductive.

We are compelled, as far as known conditions will take us, to assume that the mass of the earth is of a fairly uniform composition, and that the elements which compose it are distributed evenly.

The hypothesis entertained by many of an accumulation of heavy metals at the centre is untenable, from the fact, first noted by Newton, that all bodies of necessity lose "weight" or pressure toward the

centre as we approach the centre, at which point, in fact, there is no "weight."

In order that the regular "concentric shell" arrangement should have place, the heavier forming the interior series, the earth must have been shaped thus from the beginning, or it is an effect of gradual deposition, or else the interior is fluid, and the arrangement has been effected by gradual separation. None of these hypotheses are consonant with what we know of the diffusion and mixture of solid, viscid, or fluid masses, or with the most probable theories of the interior heat.

Gold, iron, and other heavy metals, in very small or microscopic particles, show no tendency to aggregate in viscid or liquid slags.

Nor is it allowable, in view of actual experience, to suppose that the pressure at great depths in the earth can sensibly condense its substance; for, unless the heat evolved by such pressure can be taken up by other bodies, condensation is impossible.

We are solicited by every form of experiment to seek a more general solution of the problem of central terrestrial density, and it is to be found nowhere but in the action of the earth's mass upon itself.

In order to a better understanding, let us again notice some of the arguments and facts already given. Newton maintained that the inertia of a mass is an invariable quantity, the same in all parts of the universe, and that it is the measure of the quantity of matter, and consequently of the gravitating force of the mass, whether considered as active or passive.

I have shown that this proper inertia of masses is due, not to absolute quality, or attribute of the "ultimate particles," but is a result of the inductive reaction of the substance; and that the value of this inductive reaction, for any definite mass of sensible size, taken as a base or multiplier in calculating motor forces, would be as the square of the number of units in the mass, were it not for the law of diminution of such forces by distance. But it is obvious that these differences must have the effect to *increase the inertia —and capacity for mutual gravitation—of spherical masses regularly toward their centres.* The proper inertias of planetary masses increase regularly toward their centres, with a proportionate increase of value in gravitating force.

In other words, *the effect of the earth's mass upon itself increases its efficiency as an inductive power in the solar system.*

The "mass" of a planet is therefore determined, not only by the number of formal units of matter which compose it, but by the formal and spatial relations of those units among themselves.

But the inertias of the planets are increased by the action of the sun, and of each other, and by that of the entire cosmical system. I have shown how, in this kind, and by what laws, inertias and movements are generated and necessitated.

15.—CONDITION OF COMETS APPROACHING THE SUN.

It has been noticed that a comet approaching the sun undergoes many changes; among others, it is apparently condensed upon itself, and shows signs of an increase of central heat, and of self-pressure upon its mass. *And this might by predicted of any mass of matter approaching the sun, that its inertias and gravitations upon itself will increase proportionately.*

The comet removed in space, so far distant as not to feel sensibly the effect of the sun, will have but little more than the proper inertia and self-gravity due to its own mass. But in approaching the sun it acquires a new inertia and self-gravity, because it is becoming thereby a part of the material system of the sun, as a falling mass becomes more and more a part of the earth.

16.—INCREASE OF TERRESTRIAL GRAVITY.

When the earth is making its movement toward the sun, we must suppose that the mutual inertia, and, by consequence, the mutual gravitation of its particles, increases by solar influence. When nearest to the sun its distance may be 1-30th less than when farthest removed. Let the variation be from 30 to 29 units of distance, the inverted squares of these numbers will indicate the dynamic effects to be added to the solar-inductive force of the earth upon itself by reason of increase of solar force.

SMALL quantities of glycerine are added to paper stock to give the paper greater flexibility, but especially to give copying paper the quality of taking up color readily.

GRAPHICAL ESTIMATES FOR RAILWAY EARTHWORK.

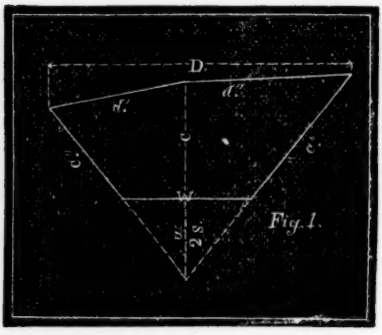
Written for "Van Nostrand's Engineering Magazine."

The multitude of devices, of more or less merit, for computing railway earthwork is an evidence, if any were needed, of the onerous character of the work and the acceptability of any relief. The following contribution to this end, by taking solidities directly from diagrams without computation from field notes kept in the usual manner, is offered to the judgment of engineers. It is believed to have at least the merit of novelty.

The method consists essentially of three diagrams, viz.: for sectional areas of thorough-cut sections, for sectional areas of side-hill sections, and for a correction to be applied to end-area solidities, to give the true solidity by the prismoidal formula.

We will first obtain the diagram for sectional areas of thorough-cut sections.

In any cross-section let



c = the centre cut.
c' and c'' = side cuts.
d' and d'' = D = width on surface.
w = width of road-bed.
s = ratio of slope, 3-2, 5-4, etc.
A = area.

Then the area will be given by the equation:

$$A = \frac{D\left(c + \frac{w}{2s}\right)}{2} - \frac{w^2}{4s}, \text{ or}$$

$$A = \frac{c}{2}D + \frac{w}{4s}D - \frac{w^2}{4s} \quad (1).$$

It is evident that letting $A = A + A_2$ equation (1) is equal to the sum of the two equations.

$$A = \frac{c}{2}D \quad (2), \text{ and}$$

$$A_2 = \frac{w}{4s}D - \frac{w^2}{4s} \quad (3),$$

both of which are the equation of straight lines, taking A and D as the variables y and x respectively; and that the value of equation (2) is independent of the particular road-bed and slope, and that of equation (3) of the depth of the centre cut. Consequently, if, laying off successive values of D along the axis of x, and of A along the axis of y, we plot equation (2) above the axis of x for successive values of c, and equation (3) below it for the different combination of values of w and s which occur in practice, we obtain a diagram from which the area of any cross-section of any variety of road-bed and slope can be obtained, by scaling along the line $x = D$ from the line above the axis of x representing the given centre cut to the line below it representing the given combination of a road-bed and slope. Such a diagram, giving areas for any kind of railway earthwork having regular slopes, has been constructed and used, but involves considerable labor and care in drawing, and to be of practical use should be engraved. The object of the present paper will be best met by giving the practical details of construction for a simple modification which is applicable to but one combination of road-bed and slope, but dispenses with the use of the scale and can be drawn on a sheet of cross-section paper in three or four hours, with very little calculation.

We will suppose a diagram is required for a road-bed of 14 feet and slopes of $1\frac{1}{2}$ to 1, on a sheet of 16×20 engraved cross-section paper graduated to tenths of an inch. Lay off along the bottom of the sheet successive values of D to a scale of 2 ft. to 1 in., the fine lines thus representing differences of 0.2 in the value of D. If we begin at the smallest possible value, 14, the last given will be 54 ft. Also, lay off up the sides of the sheet successive values of A to a scale of 50 ft. to an inch, the fine horizontal lines thus representing differences of 5 ft. in area.

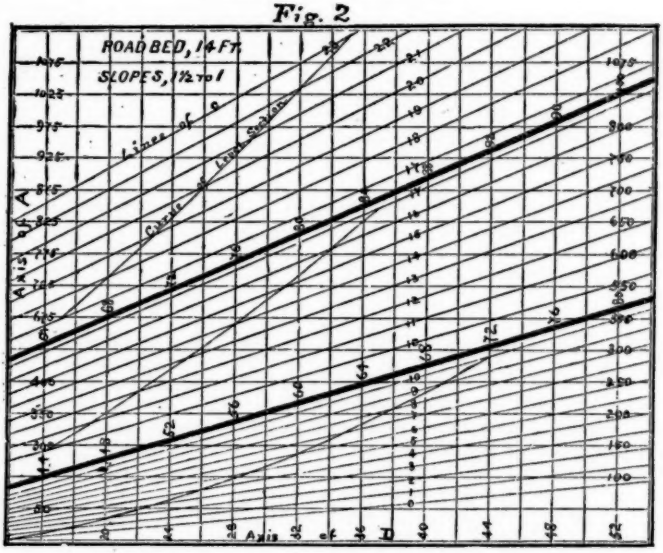
Now take D = 50 and solve equation (1) for the case $c = 0$. The first member disappears and we have

$$A = \frac{w}{4s} D - \frac{w^2}{4s} = 84 \quad (4.)$$

Lay off 84 on the diagram on line D=50. Perform the same operation, taking D = 20, when it is found A = 14. Lay off 14 on line D = 20 and through the points thus found draw a straight line which will also pass through the point D = 14, A = 0. The remaining work is almost mechanical, for since the value of c only affects the first member of equation (1), if $c = 0.2$ equation (4) becomes

Diagram of Thorough-cut Sections.

Fig. 2



$$A = \frac{0.2\,D}{2} + 84 = 5 + 84;$$

if $c = 0.4$ it becomes A = 10 + 84, etc., increasing by $\frac{D}{10}$ for every increase of 0.2 in c. Lay off then on line D=50, successive values of c varying by 0.2, *i. e.*, 89, 94, 99, 104, etc., up to say $c = 10$ ft., and in the same way on line D = 20, 16, 18, 20, 22, etc., and passing straight lines through the points thus found the diagram is complete to 10 ft.

But in continuing for cuts of more than 10 ft., the smallest value of D likely to occur in practice is about 42 ft., so that it superfluous to give smaller values on the remainder of the diagram. Accordingly, draw a heavy line just above and parallel with line $c = 10$ and lay off along it new values of D running from 42 to 82. Solve equation (1) again with $c = 10$ and D = say 50 and 80, and—letting the horizontal lines represent new values of A as found convenient—plot the result.

Then proceed as before, laying off $\frac{D}{10}$ successively up to say 17 ft., when a new heavy line is drawn, new values of D laid off, say from 62 to 102, and proceeding as before, the sheet is completed, extending up to 22 feet for any variety of surface. In continuing for higher values of c on other sheets, take the 16-in. side as the axis of x and lay off $\frac{D}{20}$ for single tenths. The method is otherwise the same.

It is well as a check to lay off values of c on one or more intermediate lines, and a smooth and unwarped sheet should be selected. Lines representing even values of c should be made prominent, and values of all the lines put at convenient intervals over the face of the diagram.

The diagram proper being finished, the "curve of level section" should be drawn on, that is, the curve of the equation $A = w\,c + c^2\,s$. This can be done without

calculation, by considering that in a level section, if c be increased by 1, D it increased by 2 s. Thus in the diagram described, the curve will pass through the points, $c = 0$, $D = 14$; $c = 1$, $D = 17$; $c = 2$, $D = 20$, etc.

As a practical example, required the area of the following cross-section:

$$\frac{13.0}{-4.0} \text{——} 7.2 \frac{24\ 7}{-11.8}.$$

Taking at the bottom of the sheet the line D= 37.7 (13.0 + 24.7), follow it up till it intersects the inclined line $c = 7.2$. Place the needle-point there and read off the horizontal lines the area = 191 ft.

Required the height of an equivalent level section to the above. Follow horizontally the line A= 191 to its intersection with the curve of level section, and read off the height required from the inclined centre cut lines, = 7.55. Suppose, by error, 7.2 above given 9.2. The point of intersection found will then lie above and within the curve of level section, its position indicating that the centre height is disproportionately great. The query at once arises whether this is correct. The ratio of c to D is always indicated by the relative position of the point obtained, and errors will thus be often detected which in computation would pass unnoticed. Areas are easily taken off to the nearest half foot if desired.

Where the ground is so irregular that intermediate side levels become necessary, it will be found most convenient to take off the area as usual, neglecting the intermediates, subsequently plotting the surface lines only of the cross-section, to obtain the area to be added to, or subtracted from, the result given by the diagram.

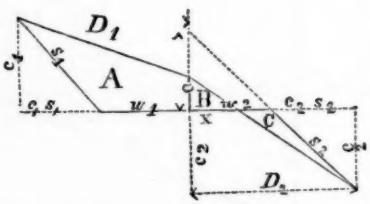
We will now take up the second diagram, providing for the cases of side-hill cross-sections, to which the previous diagram does not apply.

In any side-hill section

Let c = the centre height.
c_1 = side height in "thorough-cut" side.
c_2 = " " "side-hill" side.
D_1 and D_2 = corresponding distances cut.
w_1 and w_2 = half widths of road-bed.
s_1 and s_2 = ratio of slope in each case.
A, B, and C = parts of section as lettered in Fig. 3, *or* the areas thereof.

Since c_1 and c_2 are each set for a different road-bed and slope, the section shown in Fig. 3 in reality consists of two separate and mutually independent parts, A and B C, having the common centre height, c. The side B C again consists of two parts, B and C, one in excavation and one in embankment, which are given separately; and A and B then combined as will be seen. All areas will be expressed in terms of D and c, as in the thorough-cut diagram.

Fig. 3.



We will first obtain the formulæ of area. The trapezium A presents no difficulty, its equation being only a modification of that of a thorough-cut section. With the above nomenclature.

$$A = \frac{\left(c + \frac{w_1}{s_1}\right) D_1 - \frac{w_1^2}{2 s_1}}{2}$$

or

$$A = \frac{c}{2} D_1 + \frac{w_1}{2 s_1} D_1 - \frac{w_1^2}{2 s_1} \quad (5.)$$

For the triangle B_1—if we let $x =$ its base, we have $B = \frac{c\,x}{2}$. But, by a proportion evident from the figure,

$$x = \frac{c\,D_2}{c + c_2} = \frac{c(w_2 + c_2 s_2)}{c + c_2};$$

substituting this value we obtain

$$B = \frac{c^2 (w_2 + c_2 s_2)}{2 (c + c_2)} \quad (6.)$$

For the triangle C, we have

$$C = \frac{(w_2 - x) c_2}{2} = \frac{\left(w_2 - \frac{c (w_2 + c_2 s_2)}{c + c_2}\right)}{2} c_2,$$

and reducing

$$C = \frac{c_2^2 (w_2 - c s_2)}{2 (c + c_2)} \quad (7.)$$

The above equations (6) and (7) are expressed in terms of c and c_2. They can now be expressed in terms of c and D_2, in terms of which the diagrams are to be constructed, by simple substitution, since

D_2 is a function of c_2; but the above forms are more simple and answer equally well, as will be seen.

We have now to construct the diagram from the formulæ. It must evidently consist of separate and subordinate diagrams for A, B, and C. In each case values of D are laid off horizontally, and of area vertically, and the equation plotted for successive values of c. We will assume as limiting dimensions a maximum value of 12 ft. for c_1 and of 6 ft. for c and c_2.

The diagram of A, which comes first in order, consists of right lines, and is the same in principle as the thorough cut diagram. Solve Eq. (5) for the case $c = 0$, letting $D_1 = 10$ and 20 successively. Plot the results on the proper vertical lines of D_1, above the points thus obtained lay off $\frac{D}{4}$ continuously, for differences of 0.5 in the value of c, up to $c = 6$, and pass straight lines through the points obtained.

The equation of B and of C is that of a curve, to plot which, points on each line of c must be determined at intervals. In practice, since the curves are not sharp, points determined for even feet of c_2 are sufficiently close; and since these triangles are always small, only lines of c for even feet need be drawn. The preliminary computation—thus reduced to small limits—is done most easily by making a rough pencil table with columns for each of the different terms of the formula, for each value of c_2 from 1 to 6. The last column of each of these tables—consisting of the areas sought—is then copied into a second table of results, and headed, *not* with the value of c_2, under which it was computed, but with the *value of* D_2 *corresponding to it.* These tables are given below for four cases of common occurrence.

TABLES USED IN CONSTRUCTING DIAGRAMS OF B AND C.

Centre ht.	*Areas of B.* $w = 7$ $s = 1\frac{1}{2}$ *to* 1.							*Areas of C.*						
	D=7	D=8.5	D=10	D=11.5	D=13	D=14.5	D=16	D=7	D=8.5	D=10	D=11.5	D=13	D=14.5	D=16
0	0.0	0 0	0.0	0 0	0 0	0 0	0.0	0.0	3.5	7.0	10.5	14 0	17.5	21.0
1	3 5	2.1	1.7	1.4	1.3	1.2	1.1	0.0	1.4	3.7	6.2	8.8	11 5	14.1
2	7 0	5.7	5.0	4 6	4.3	4 1	4.0	0.0	0.7	2.0	3.6	5.3	7.1	9 0
3	10.5	9.3	9 0	8.6	8 4	8 2	8 0	0.0	0 3	1.0	1.9	2.9	3.9	5.0
4	14 0	13 6	13.3	13.1	13 0	12.9	12.8	0 0	0 1	0 3	0.6	1.0	1 4	1.8
4½	16.3	16.3	16.3	16.3	16 3	16 3	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0 0

Centre ht.	*Areas of B.* $w = 7\frac{1}{2}$ $s = 1\frac{1}{2}$ *to* 1.							*Areas of C.*						
	D=7.5	D=9.0	D=10.5	D=12.0	D=13.5	D=15.0	D=16.5	D=7.5	D=9.0	D=10.5	D=12.0	D=13.5	D=15.0	D=16.5
0	0.0	0.0	0.0	0.0	0.0	0.0	0 0	0·0	3.8	7 5	11.3	15.0	18 8	22 5
1	3.8	2.2	1.7	1.5	1 4	1.3	1.2	0·0	1 5	4.0	6.8	9 6	12.5	15.4
2	7.5	6 0	5.2	4 8	4 5	4.3	4 1	0·0	0.7	2 2	4.1	6 0	8 0	10.1
3	11 3	10.1	9.5	9.0	8 7	8.5	8.3	0.0	0 3	1 2	2.3	3.4	4 7	6.0
4	15.0	14.4	14.0	13 7	13 5	13.3	13.2	0 0	0 1	0 5	1 0	1.5	2.1	2 7
5	18.8	18 2	18 8	18 8	18.8	18 8	18 8	0.0	0.0	0.0	0.0	0 0	0.0	0.0

Centre ht.	*Areas of B.* $w = 9$ $s = 1\frac{1}{2}$ *to* 1.							*Areas of C.*						
	D=9	D=10.5	D=12	D=13.5	D=15	D=16.5	D=18	D=9	D=10.5	D=12	D=13.5	D=15	D=16.5	D=18
0	0.0	0 0	0.0	0.0	0.0	0 0	0 0	0 0	4.5	9 0	13 5	18 0	22.5	27.0
1	4.5	2 6	2.0	1.7	1.5	1.4	1 3	0.0	1.8	5.0	8.4	12.0	15.6	19.3
2	9 0	7.0	6.0	5.4	5.0	4.7	4.5	0 0	1.0	3.0	5 4	8.0	10.7	13.5
3	13 5	11.8	10 8	10.1	9.6	9.3	9.0	0.0	0 6	1 8	3.5	5 1	7 0	9 0
4	18.0	16.8	16 0	15.5	15 0	14 7	14 4	0.0	0.3	1 0	1.9	3 0	4.2	5.4
5	22 5	21.9	21.4	21.1	20 8	20.6	20.5	0.0	0.1	0.4	0 8	1.3	1 9	2.5
6	27.0	27.0	27.0	27.0	27.0	27.0	27.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0

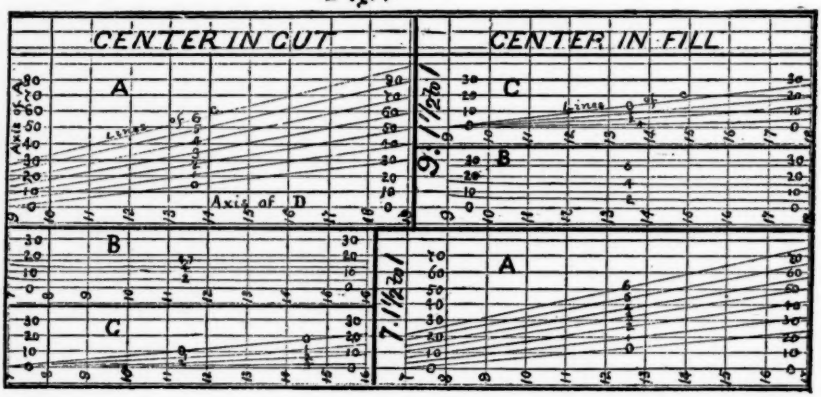
Centre ht.	*Areas of B.* $w=10$ $s=1\frac{1}{2}$ *to* 1.							*Areas of C.*						
	D=10	D=11.5	D=13.0	D=14.5	D=16	D=17.5	D=19.0	D=10	D=11.5	D=13.0	D=14.5	D=16.0	D=17.5	D=19.0
0	0.0	0.0	0.0	0 0	0.0	0.0	0.0	0.0	5.0	10 0	15.0	20 0	25 0	30 0
1	5.0	2.9	2.2	1.8	1.6	1.5	1.4	0.0	2.1	5.7	9.6	13.6	17.7	21 9
2	10.0	7.7	6 5	5.8	5 3	5.0	4.8	0.0	1.2	3.5	6 3	9.3	12 5	15.6
3	15 0	12.9	11 7	10 9	10.3	9.8	9.5	0.0	0.7	2.2	4 1	6 3	8.6	11 0
4	20 0	18.4	17.3	16 6	16 0	15.6	13.6	0 0	0.4	1.3	2 6	4 0	5 6	7 2
5	25 0	24.0	23 2	22.7	22.2	21 9	21 6	0.0	0 2	0.7	1.4	2.2	3.1	4.1
6	30.0	39.6	29.3	29 0	28.8	28 6	28.5	0.0	0 1	0.3	0.5	0.8	1 1	1.5

It must be borne in mind in calculating these tables that the greatest possible value of c is $\frac{w_2}{s_2}$, which distance, laid off on the centre height c prolonged, marks its insection with the slope s_2. The triangle B then has its maximum value,

$$B = \frac{w_2^{\,2}}{2 s_2} \text{ and } C = 0.$$

Also, when c has its minimum value, 0, the equation of C reduces to $C = \frac{w_2 c_2}{2}$, and similarly when $c_2 = 0$, $B = \frac{w_2 c}{2}$.

Fig. 4.



The construction of the diagram from these tables is shown in Fig. 4, a reduction to half scale of a side-hill diagram for a road having 14 and 18 ft. road-beds and all slopes $1\frac{1}{2}$ to 1. To construct this take a piece of cross-section paper 6 × 15 in., graduated to tenths, and beginning in the lower left hand corner lay off values of D from 7 to 16, and plot the table of c for the case $w = 7$, $s = 1\frac{1}{2}$ to 1. Since the area of C is in inverse ratio to c, the line c, = 0—a right line passing through the origin—is the highest, and the curved lines, $c = 1, 2, 3$, etc., come consecutively below. Pass these lines through the points obtained by plotting the table, and above the diagram thus obtained construct the diagram of B for the same case. Here the line

$$c = \frac{w}{s} = 4\tfrac{2}{3}$$

—a right line parallel with the axis of D—is the highest, and the flat and nearly parallel curved lines $c = 4, 3, 2$, etc., come consecutively below. At the end of these two diagrams construct the diagram of A for the same case, and above the three diagrams now completed, construct in inverse order, as seen in Fig. 4, the three diagrams for the case $w = 9$, $s = 1\frac{1}{2}$ to 1. As thus arranged the first *vertical* column of 3 diagrams gives the areas of A, B, and C, when the centre, c, is in cut, and the second when in fill. Head the columns correspondingly, and place values of lines, etc., conveniently over the face of the diagram. If a third or fourth class of road-bed occur on the

work, plot its diagrams above or below the two shown in the figure and use the pair applying to the given cross-section.

The diagram as thus constructed is used with equal facility with the thorough-cut diagram, and since the general arrangement of both is similar no special care or thought is required in passing from one to the other. Thus, in taking off areas from the cross-section book a side-hill section is met with, as

$$\frac{18\ 4}{+6.3} + 1.6 - \frac{12.4}{3.6}.$$

The assistant—always beginning on the thorough-cut side of the section—calls off "side-hill, 1.6 cut, 18.4." Take the side-diagram under column "centre in cut," and beginning always with the diagram of A, follow up line D = 18.4 to its intersection with line $c = 1.6$ which is found to be on the horizontal line A = 43. The assistant then calls "12.4" Taking the diagram of B immediately below, follow the vertical line D=12.4 to its intersection with the curved line $c = 1.6$, obtaining 3 as the area of B, which the assistant adds to the 43, and sets down in the cut column of areas, while from the same notes of D = 12.4, $c = 1.6$, the area of the third triangle C is taken from its diagram and placed in the fill column of areas, and the work is proceeded with. In practice the delay for side-hill cross-sections, even when very frequent, is inappreciable.

The end area solidities which have next to be sought can be obtained from the tables in common use, or still better, by an improvement due to Mr. Chas. A. Smith, C. E., Asst. Prof. of Civil Engineering, in Washington University, can be obtained directly from the diagrams, by constructing them to give areas multiplied by the factor $\frac{100}{54}$, when the solidity for a full station is given by simple addition. This involves no change in the construction of the diagrams except that the scale of $A \times \frac{100}{54}$ should be 100 to an inch instead of 50, and that in the thorough-cut diagram values of c should be laid off, for convenience, on lines D = 54, 27, etc., to avoid fractional increments. The requisite changes in the tables for constructing the side-hill diagram are easily made.

We have now reached the third step in the process, the determination of the true solidity by the prismoidal formula, which is obtained by means of a connection to be applied to the end-area solidity. Several methods on this principle are already in use and can be used if preferred, but as a rule are approximate only. The following formula and diagram, by Mr. Chas. A. Smith, C. E., gives an absolutely correct result, and in terms of the same dimensions, D and c, which have been already employed in the previous diagrams.

In any prismoid, letting A and A' = the areas of the end-sections, we have by Eq. (1), the basis of the thorough-cut cross-section diagram.

$$A = \frac{c}{2} D + \frac{w}{4s} D - \frac{w^2}{4s}, \qquad (8.)$$

and

$$A' = \frac{c'}{2} D' + \frac{w}{4s} D' - \frac{w^2}{4s} \qquad (9.)$$

Adding Eq. (8) and (9) together, dividing by 2 and multiplying by l we obtain as the end-area solidity

$$S_E = \left\{ \frac{c}{2} D + \frac{c'}{2} D' + \frac{w}{4s}(D+D') - \frac{2w^2}{4s} \right\} \frac{l}{2},$$

or

$$S_E = \left\{ \frac{3c}{2} D + \frac{3c'}{2} D' + \frac{3w}{4s}(D+D') - \frac{6w^2}{4s} \right\} \frac{l}{6}. \qquad (10.)$$

We have now to obtain the *true* solidity, $= s$, to do which we must first obtain the area of the middle section, every dimension of which is equal to the half sum of the corresponding parts of the end sections, consequently

$$A_M = \frac{c+c'}{4} \frac{D+D'}{2} + \frac{w}{4s} \frac{D+D'}{2} + \frac{w^2}{4s} \qquad (11.)$$

By the prismoidal formula $S = (A + A' + 4\ A_M)\frac{l}{6}$, or substituting the different values of A as given in Eq. (8), (9) and (11), and placing similar terms together

$$S = \frac{c}{2} D + \frac{c'}{2} D' + (c + c') \frac{D + D'}{2} + \frac{3w}{4s}(D + D') - \frac{6w^2}{4s} \qquad (12.)$$

Subtracting Eq. (12) from (10), terms containing w and s disappear, and we have

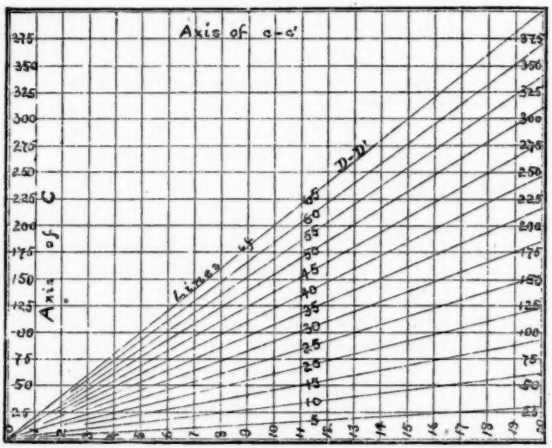
$$S_E - S = \frac{c D + c' D' - c D' - c' D}{2} \frac{l}{6},$$

or, letting $S_E - S = C$.

$$C = (c - c')(D - D') \frac{l}{12} \qquad (13.)$$

In diagramizing, let $l = 100$ ft., and divide the last member by 27 to give results in cubic yards, giving the equation the form $C = \frac{D-D^1}{3.24}(c-c)$. Let $c-c^1 =$ the variable x, and on a sheet of 16×20 cross-section paper lay off values for it horizontally to a scale of 1 ft. to an inch. Let C = the variable y, and lay off values for it vertically to a scale of 20 or 25 cubic yards to an inch, and—theoretically—plot the equation for successive values of $D - D^1$. Practically, this is done by laying off continuously on a given line of $c - c^1$, the corresponding values of C for successive increments of 1 ft. in the value of $D - D^1$. If we select those lines of $c - c^1$, which are multiples of 3.24, *e. g.*, 6.48, 12.96, 19.44, these increments become integral for the cases supposed, being 2, 4, 6, respectively,

Fig. 5



and can be laid off almost mechanically. Pass right lines through the points thus obtained, which also pass through the origin in the left hand lower corner, and the diagram is complete, applying, as is evident from the formula, to any combination of road-bed and slope.

To use the diagram, we have already obtained the values of D and D^1, in getting end-area solidities. The difference between these, and also the value of $c - c^1$, we obtain mentally, or by previous subtraction, and finding, as in the other diagrams, the point of intersection of the lines which represent these data, the correction for a full station of 100 ft. is given by the horizontal line passing through it, set down in pencil in a column for the purpose, and subsequently inked, in taking the proper fractional parts for fractional stations. The total amount of these corrections for each cut or for the whole division is then obtained and subtracted from the end-area solidity. There is nothing gained by applying the correction to each individual solid, and by this method the work can be done at any time when leisure offers, with great advantage to the probable accuracy.

It is thought that this system of computation will be found, on trial, to offer considerable advantages. Graphical methods have been little used for this purpose, and the diagrams may seem complicated in construction, but it is believed that their practical use will be found to be simple and direct, and to contain in a high degree accuracy and speed. The error of observation need never exceed ½ sq. ft. of area, considerably within the probability of error from neglecting half-tenths in the field work, and similar causes, and beyond this the results are mathematically correct. The seemingly greater precision of tables or computation, it is needless to say, is purely fictitious. As the work is a simple matter of eyesight, and the result in each

case is given at once, the work is rapid and not fatiguing, and careless errors are very rare. End-area solidities can be taken off by two men, with ordinary diligence, at the rate of 400 cross-sections per hour.

THE TEMPERATURE PRODUCED BY SOLAR RADIATION.

From "Nature."

By J. ERICSSON.

Sir Isaac Newton determined the intensity of solar radiation by observing the increment of temperature of dry earth on being exposed to the sun. In the latitude of London at midsummer, dry earth acquires a temperature of 150 deg. in the sun at noon and 85 deg. in the shade, difference about 65 deg. Fahr. This difference Sir Isaac Newton regarded as a true index of the intensity of solar radiation; hence his celebrated demonstration proving that the comet of 1680 was subjected to a temperature 7,000 times higher than that of boiling water (212 deg. × 7,000 = 1,484,000 deg. Fahr.*) The comet when in its perihelion being within one-third part of the radius of the sun from his surface, we have to add the diminution of temperature, 0.44, attending the dispersion of the rays in passing through the solar atmosphere and the remainder of the stated distance from the sun. Accordingly, the demonstration showing that the comet of 1680 was subjected to a temperature 7,000 times higher than that of boiling water, establishes a solar temperature exceeding 2,640,000 deg.; and if we add 0.21 for the retardation of the rays in traversing the terrestrial atmosphere, it will be found that the temperature deduced from the experiments with incandescent radiators, and our actinometer observations, differs scarcely ⅓ from that roughly estimated by the author of the "Principia." In order to comprehend fully the merits of the method of determining solar intensity conceived by his master mind, let us imagine an extended surface of dry earth, one half of which is shaded, the other half being exposed to the sun. Dry earth being a powerful absorbent and radiator, and at the same time a bad conductor, the central portion of the supposed surface evidently cannot suffer any loss of heat by lateral radiation; while the nonconducting property of the material prevents loss by conduction laterally or downwards. Consequently, no reduction of temperature can take place excepting by radiation in the direction of the source of the heat. Removing the shade, during an investigation, it will be found that, notwithstanding the uninterrupted radiation of the exposed substance upwards, the intensity will gradually increase until an additional temperature of about 65 deg. Fahr. has been acquired. Indisputably this increase of temperature is due to unaided solar radiation. Evidently the accidental interference of currents of air need not be considered. Besides, if the dry earth is confined within a vacuum, such interference may be entirely obviated. It is scarcely necessary to point out that the generally adopted mode of measuring the sun's radiant heat by thermometers, is in direct opposition to the principle involved in the method under consideration. The meteorologist, in place of preventing the bulb from radiating in all directions and guarding against loss of heat by convection, puts his thermometer on the grass, or suspends it on a post, one half of the convex area of the bulb receiving the sun's radiant heat, while the other half is permitted to radiate freely, the whole being exposed to the radiation from surrounding objects and to the refrigerating influence of accidental currents of air, in addition to the permanent current produced by the ascending heated column above the bulb. This explains the cause of the perplexing discrepancies in meteorological records. The extent of the diminution of intensity of solar radiation occasioned by cold air acting on the bulb, and by the latter radiating freely in all directions, is demonstrated in the most

* Sir Isaac Newton has been criticised for comparing the temperature to that of red-hot iron, "a term of comparison indeed of a very vague description," it is said in "Outlines of Astronomy." This criticism is far from being correct, since the demonstration clearly shows what is meant by the term red-hot, viz., a temperature 3.5 times that of boiling water. The reference to red-heat, exceeded "2,000 times," was evidently intended to furnish some adequate notion of the inconceivably high degree of temperature involved in the computation.

conclusive manner by the result of observations made with the instrument described by Père Secchi in his recent work "Le Soleil" (p. 267). "During a great number of observations made at Rome," says the author, "the difference between the two temperatures (that indicated by the thermometer exposed to the sun and that of the surrounding casing) was 12.06 deg. (21.70 deg. Fahr.); during days when the sky was clearer, it rose to 14 deg." Consequently, the highest temperature indicated by the instrument referred to, was 25.2 deg. Fahr., against 66.04 deg., which is the true maximum solar intensity in the latitude of Rome. It will be seen then, that, by exposing the bulb of the thermometer in the manner pointed out,

TABLE A.

SHOWING THE TEMPERATURE PRODUCED BY SOLAR RADIATION AT NOON, FOR EACH DEGREE OF LATITUDE, WHEN THE EARTH IS IN APHELION. NORTHERN HEMISPHERE.

	Latitude	Solar intensity at Noon.	Latitude	Solar intensity at Noon.	Latitude	Solar intensity at Noon.	Latitude	Solar intensity at Noon.	
	Deg.	Fah.	Deg.	Fah.	Deg.	Fah	Deg.	Fah.	
Equator.....	0	65 30	24	67 20	49	64.95			
	1	65.45	25	67 19	50	64 77			
	2	65.60	26	67 18	51	64.58			
	3	65.75	27	67.17	51.28	64.48	....	....	Greenwich.
	4	65 89	28	67 14	52	64.38	72	58 69	
	5	66.02	29	67.10	53	64.17	73	58.31	
	6	66.15	30	67.05	54	63 96	74	57.92	
	7	66 27	31	66 99	55	63 74	75	57.52	
	8	66.39	32	66.93	56	63.51	76	57.10	
	9	66 49	33	66 87	57	63.28	77	56.67	
	10	66.58	34	66 80	58	63 04	78	56 24	
	11	66.66	35	66 73	59	62 79	79	55.79	
	12	66.73	36	66.66	60	62.53	80	55.32	
	13	66.80	37	66.58	61	62.25	81	54.84	
	14	66.87	38	66.49	62	61.96	82	54.35	
	15	66.93	39	66 39	63	61 65	83	53 84	
	16	66 99	40	66 27	64	61.34	84	53 32	
	17	67.05	41	66 15	65	61.03	85	52 78	
	18	67.10	42	66.02	66	60 72	86	52 23	
	19	67.14	43	65.89	66 30	60 57	....	....	Arctic Circle.
	20	67.17	44	65.75	67	60 41	87	51 68	
	21	67 18	45	65.60	68	60.09	88	51.11	
	22	67 19	46	65.45	69	59.76	89	50.52	
	23	67 20	47	65 30	70	59 42	90	49.91	North Pole.
Tropic of Cancer	23 30	67.20	48	65.18	71	59.06			

TABLE B.

SHOWING THE TEMPERATURE PRODUCED BY SOLAR RADIATION IN THE EARTH'S ORBIT; ALSO THE GRADUAL DIMINUTION OF TEMPERATURE DURING THE FIRST HALF, AND THE GRADUAL INCREMENT OF TEMPERATURE DURING THE SECOND HALF-YEAR:

Dates.	1st.		5th.		10th.		15th.		20th.		25th.	
Months.	Max.	Diff.	Max.	Diff.	Max.	Diff.	Max.	Diff.	Max.	Diff.	Max.	Diff.
	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah	Fah.	Fah.	Fah.	Fah.
January.....	90 72	5 88	90.70	5,86	90,67	5 83	90,62	5,78	90,54	5 70	90 44	5,60
February.....	90 28	5,44	90,16	5 32	90,01	5,17	89 83	4,99	89,64	4,80	89,43	4 59
March.....	89 27	4 43	89.09	4.25	88 86	4 02	88,62	3 78	88,37	3 53	88.12	3.28
April.....	87 77	2,93	87 57	2 73	87 32	2 48	87,07	2.23	86 83	1,99	86,59	1,75
May.....	86.32	1,48	86.15	1,31	85,95	1 11	85,76	0.92	85 58	0,74	85 43	0.59
June	85,22	0.38	85 13	0 29	85,03	0.19	84,96	0 12	84 90	0 06	84 86	0 02
July.....	84 84	0.00	84 85	0 01	84 87	0 03	84 92	0,08	84,99	0,15	85,07	0.23
August.....	85.22	0,38	85,34	0 50	85 49	0.65	85,65	0,81	85,83	0.99	86 03	1.19
September.....	86,32	1.48	86,50	1,66	86,73	1,89	86 97	2,13	87 22	2 38	87,47	2,63
October.....	87,77	2.93	87 97	3,13	88 22	3,38	88.47	3,63	88,71	3,87	88,95	4.11
November.....	89,27	4 43	89,43	4,59	89,64	4 80	89,83	4 99	90 01	5,17	90,16	5,32
December.....	90,33	5,49	90.42	5,58	90,52	5 68	90.61	5.77	90,66	5,82	90,70	5 86

TABLE C.

TEMPERATURES PRODUCED BY SOLAR RADIATION, JUNE 26, 1871, COMPARED WITH THE TEMPERATURES ENTERED IN THE TABLE CONSTRUCTED 1870, FOR CORRESPONDING ZENITH DISTANCES. MEAN DISCREPANCY = 0.26° FAHR.:

	ZENITH DISTANCES—DEGREES.								
	57	58	59	60	61	62	63	64	65
	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.	Fah.
Observations June 26, 1871.....	55.64	55.00	53.83	53 51	53 41	52.76	52.23	51.70	51 27
Table of 1870	55.09	54 60	54.10	53.58	53.05	52 50	51 90	51 40	50.81

it is possible to reduce the temperature produced by solar radiation to 0.38 deg. of the actual temperature.

It will be proper to observe with reference to the accompanying tables—constructed in accordance with the result of investigations continued winter and summer during three years—that the opinion expressed by the Director of the Roman Observatory, respecting solar intensity at different seasons, is wholly at variance with the facts established by my numerous observations. The question was raised last summer whether the high temperature during the "heated term" would not charge the atmosphere with an additional amount of vapor capable of retarding the passage of the heat rays, thus rendering the figures entered in my tables to some extent unreliable. Accordingly, during the solstice, June 26, 1871, the sky being very clear, the actinometer was put in operation for the purpose of ascertaining with critical nicety whether the atmosphere which had been loaded with vapor for several weeks previously, possessed any unusual property tending to check the heating power of the sun's rays. The observations were made late in the afternoon under great zenith distance and increased atmospheric depth, in order to subject the heat rays to an additional retardation from the supposed vapors. The result is recorded in Table C, by which it will be seen that the reduction of temperature was only 0.26 deg. Fahr., a difference too small to call for any explanation. The result of the observations made during midwinter are equally conclusive with reference to the permanency of solar energy at all seasons. Among others may be mentioned that of January 17, 1871, the zenith distance being 61 deg. 30 min., the actinometer remained perfectly stationary at 58.73 deg. Fahr., from 12h. 10m. to 12h. 20m., P. M. The table just referred to shows that on June 26, 1871, the actinometer indicated 53.08 deg. when the sun's zenith distance was 61 deg. 30 min. Hence during midwinter the temperature proved to be 58.73 deg. — 53.08 deg. = 5.65 deg. higher for corresponding zenith distance, than during the summer solstice. By reference to Table B it will be seen that owing to the diminished distance between the sun and the earth, the increment of temperature on January 17, ought to have been 5.75 deg., discrepancy = 0.1 deg. Fahr. In the face of such facts it is idle to contend that the temperature produced by solar radiation under corresponding zenith distance and a *clear sky*, varies from any other cause than the varying distance between the sun and the earth. Of course there are many regions in which the sun, in consequence of local peculiarities, but seldom acts with maximum energy. Alaska, for instance, is hardly ever favored with a full amount of solar heat; nor does Rome, we are now informed by the Italian physicist, receive maximum solar heat excepting during winter, owing, it may be imagined, to the absorptive power of the atmosphere of the Campagna during summer.

Without entering the field of speculation, let us consider that the established diminution of solar heat on the ecliptic, nearly 18 deg. Fahr., proves the existence of a powerful retarding medium, and points to the presence of a permanent mass of aqueous matter in the higher regions of the atmosphere; necessary, it may be urged, to regulate terrestrial temperature and render vegetable life possible under the destructive vicissitudes of heat and cold, inevitable in the absence of a permanent regulator. The assump-

tion that the supposed mass of aqueous matter is nearly invariable, and at all times present, can alone account satisfactorily for the remarkable fact that, whenever a clear sun is presented, either by the opening of the clouds or by their disappearance, the actinometer indicates the same temperature, subject only to the variations depending on the sun's zenith distance, and the varying position of the earth in its orbit. The variation of temperature produced by the latter cause is entered in Table B, for every fifth day in each month. This table, an extract from a more elaborate one showing the temperature for every day in the year, the meteorologist will find indispensable to harmonize observations made at different seasons. It may be mentioned that the attempt to construct a curve, the ordinates of which would determine the temperature for different zenith distances, at first met with apparently insuperable difficulty. The result of observations made at different seasons under the most favorable circumstances, failed to produce a regular curve until the change of temperature corresponding with the varying distance between the sun and the earth was determined and introduced in the calculation. This at once harmonized the previously conflicting observations and rendered the task easy of perfecting the curve, and obtaining ordinates consistent with the observed temperature produced by solar radiation at different seasons and different zenith distances.

Regarding Table A, it will suffice to state that it is based upon our acquired knowledge of the temperature produced by solar radiation at given zenith distances when the earth is in aphelion. Evidently if we know that, for instance, when the sun's zenith distance is 43 deg. the temperature is 60.57 deg.Fahr., we know also that this is the temperature at noon on the Arctic Circle, the latter being 43 deg. from the ecliptic at the summer solstice. Again, the North Pole being 66 deg.30 min. from the ecliptic at the same time, we find by referring to the figures entered in the table of zenith distances and temperatures (previously published) that the depth of atmosphere to be penetrated by the rays when the sun is 66 deg. 30min.from the zenith, is 2.444 times greater than on on the ecliptic; and that, therefore the radiant intensity, as shown in the table, is reduced from 67.20 deg. at the tropic of Cancer to 49.91 deg. Fahr. at the pole.

Possibly it may be found necessary to introduce a correction for the difference of atmospheric density in the higher latitudes; but at present I deem it inexpedient to complicate the matter by applying a correction which obviously cannot affect the general result.

THE INDICATOR AND THE BRAKE DYNAMOMETER.

Translated from "Deutsche Industrie Zeitung."

In the "Mittheilungen des Gewerbevereines für Hanover," 1871, p. 38, Prof. Ruhlmann discusses the question, in what relation the mechanical work shown by the indicator of a steam engine stands to the effective work which is transmitted to the axle of the fly-wheel. Of these results, the first is of importance only to the constructor and machinist, while the second is of import to all who would obtain productive manufacturing work from the engine. The indicator diagram is not only the machinist's sole means of determining the pressure in the cylinder and the work of the piston, but it also determines whether the dimensions of the steam passages are suitably adjusted, whether the distribution is correct, and also how great is the sum of resistances in friction of piston, piston-rod, etc. All these circumstances are of importance to the purchaser of a steam engine, but he should also know what amount of useful work is communicated to the fly-wheel, for by means of this he changes form or place of a body, thereby earning money. So in the sale of an engine, or the settlement of an important contract of sale, the important question is, what is the amount of useful or effective work? This can generally be found by three methods: The first, by calculation; the second, by means of a brake-dynamometer (Prony's, which is applied directly to the axle); the third, by the indicator-diagram, which gives the indicator horse-power, from which the effective or actual brake power can be derived. The method by

calculation supposes certain mathematical formulas, such as those given by Redtenbacher, in his "Resultanten," and by Völckers, in his little volume, "Der Indicator." But these are not entirely satisfactory, since they do not correctly take into account all passive resistances, and since the empirical coefficients heretofore obtained require correction.

Local hindrances are sometimes in the way of direct measurement by brake; such as the want of proper place for its application, the length of time and the labor which are often necessary, and in large engines the possibility of accident, perhaps with loss of life.

The simplest method is the third: that is, to deduce from the horse-power indicated by diagram (N i), the corresponding brake horse-power (N b), by multiplication by coefficients derived from a great number of experiments upon engines of different dimensions. This method generally gives only approximate results; hence it is important to mark out the limits within which performance and demand must lie. Prof. Ruhlman considers it sufficient for this purpose to tabulate in chronological order the results of all published experiments with those obtained by himself.

The earliest comparative experiments in determination of effective work were made by the engineers, Jordan and Völckers, in the autumn of 1856, at Clausthal, with a Woolf's beam engine. The small cylinder had a diameter of $9\frac{1}{2}$ in., and the piston a stroke of $1\frac{3}{4}$ ft.; the large cylinder was $15\frac{1}{4}$ in. in diameter, and the stroke was $2\frac{1}{2}$ ft. The results were as follows:

No. of experiments.	Tension in boiler in lbs. to square inch.	Revolutions of fly-wheel per minute.	Nb.	Ni.	$\frac{N}{Ni.}$
1	48.0	36.0	14.56	23.60	0 617
2	43.4	36.87	12.104	15 40	0.786
				Mean	0.710

In 1860, Prof. Rühlman made experiments with a small horizontal engine. The cylinder had a diameter of 10.25 English inches, and the stroke was 21.85 in. The results were as follows:

	Mean tension, Eng. lbs. to sq. in., by indicator.	Velocity of piston, Eng. ft. per sec'd.	Nb.	Ni.	Nb. Ni.	
1	30.31	4.075	13.60	15.91	0.85	Full supply.
2	30.46	3.962	13.86	15.54	0.89	
3	35.13	2.717	11.23	12.29	0.91	
4	33.63	4.075	14.90	17.65	0.84	
5	32.25	3.056	9.50	11.55	0.82	Half supply.
				Mean	0.86	

The French engineer, Burel, published the results of an experiment with a large 80-horse-power beam engine (Woolf), in the "Memoires de la Soc. des. Ing. Civ." The indicator diagram showed a work of 93.30 horse-power, and the brake gave a work of 80.312 horse-power; hence

$$\frac{Nb}{Ni} = \frac{80312}{93300} = 0.86$$

The best managed and most trustworthy of the experiments heretofore made, are probably those of Grosseteste and Hallauer, made with a double cylinder Woolf beam engine, at Mühlhausen. The dimensions were

Small piston { diameter, 0.50 metres.
stroke, 1.524 "

Large " { diameter, 1.10 "
stroke, 2.10 "

The number of revolutions varied from 21.333 to 21.494 per minute. The tension in the steam jacket varied from 4.843 to 4.395. Measurements of the water and coal were very carefully made. A Watts indicator was used. The experiments lasted for five days. The results were as follows:

Day of ending work.	Nb.	Ni.	Nb. Ni.
3	189.802	210.047	0.903
4	190.856	212.846	0.896
5	193.668	217.749	0.889
		Mean	0.896

A fifth case of comparison of indicator

and brake occurred to Prof. Ruhlman in 1869, when there was a dispute between a maker and a purchaser. The engine had a horizontal cylinder of $13\frac{1}{4}$ (English) in. diameter and a stroke of $34\frac{3}{4}$ in. The experiments resulted as follows:

	Admission.	Mean tension by indicator lbs to inch	Revolutions per min.	Nb.	Ni.	$\frac{Nb.}{Ni.}$
1	03.41	29.2	56	36.90	49.50	0 745
2	03·60	33.2	55	40.80	55.30	0.738
3	01.55	17.1	57	20.71	29.53	0.702
4	01.57	18.6	55	22.40	31.00	0.723
					Mean	0.727

The sixth case consists of experiments made with a double cylinder locomotive at Hanover. Cylinder of $6\frac{1}{2}$ (English) in. diameter; stroke, 10 in. Results in the following table:

	Revolutions per minute.	Mean tension by ind. lbs. to sq. in.	Nb.	Ni.	$\frac{Nb.}{Ni.}$
1	105	27.70	7.87	9.74	0.808
2	116	30.80	10.35	11.976	0.864
3	120	29.37	9.63	11.81	0.815
4	140	31.60	12.49	14.83	0.842
5	120	34.16	12.42	13.74	0.909
				Mean	0.847

From the above results we may at least conclude that no smaller ratio than 0.70 between brake and indicator is permissible, and that not more than 0.90 is attainable.

GOTHIC AND RENAISSANCE CHURCH RESTORATION.

From "The Builder."

When the history of church and temple architecture comes to be written without thought of anything but the mere facts, and their obvious inferences, what a very curious and somewhat unintelligible history it must be. If the precise mode of conducting ceremonies in the old Parthenon could be come at—and what a pity it is that it cannot—if the defined use of every part of that structure could be discovered, we are quite sure that not a single stone in it would be found to have been put up for nought. Every part of it, both inside and outside, and its decoration, must have had its proper use and significance, and certainly would never have been there at all if it had had none. So of every heathen temple probably in existence from Egypt to India. But nowadays, as the world has grown older and wiser, things are altered; churches and chapels are built, and being built and decorated as well every day, and having parts attached to them for which those who are to make use of them have no need, and who do not know what to do with these strange additions to the bare and actual requirements of the time and circumstances. Some old forms and arrangements have been copied and brought into existence, and made to add, as it is thought, to the architectural and artistic effect of the structure. What was a useful and artistic necessity in the old building, or model, is in the modern copy of it simply an *artistic* necessity. Nothing can possibly be stranger or more worthy of a little thoughtful consideration, and we have been led to it from seeing lately one or two of the City churches now in course of "restoration," as it is called; a chapel now building, with a tall bell-tower attached, but without any bells to fill it, or apparent usefulness or practical purpose, and from the sight—a lamentable one—of the Morning Chapel in St. Paul's Cathedral, now in course of restoration, or whatever other work may be considered best decriptive of what is going on in it, or being done to it. This is modern architecture in practical working, and it would seem to go some way to prove that a really modern architecture, or architectural restoration, does not exist, but only a mode

of copying blindly, or following blindly, a something or a somebody gone before us, but passed away. The "restoration" of an old Gothic church would seem to be, to a certain extent, a straightforward sort of work, and to consist simply of undoing all that the last century did in it. Galleries are pulled down; all the closed pews are condemned; the walls and roof are well scraped, and white-wash and yellow-wash got rid of, and the bare wall-surface is made visible; the old pulpit, reading-desk, and clerk's desk come down; the quaint communion-table makes way for a more imposing piece of church furniture; and, in short, by the time all is done, no one going into the building could possibly know it for the same structure; it all looks so new and dainty! This is called "restoration," *i. e.*, the church is restored to what it may be supposed to have looked like four or five centuries ago. What a surprise it would be to modern restorers, if but some old church could be discovered, and exhumed from the dust of centuries, and exposed to modern view, with everything in it just as it was left after some morning "function." What would be done with it, could it be "restored?" and what would become of its furniture, vestments, and books?

But far different is the fate of the Renaissance or Italian City church. For some time, as all know, no one seems to have thought of restoring any of this style of architecture church; they were all left to go on in their own old-fashioned way, so that any man going into a City church went literally and truly into the house of his fathers; nay, the very voices in it seemed of the past, and to come almost from the grave, all looked and sounded so old and dusty. But the spirit of modern improvement and reasonableness has at length entered them, and they are now in active course of what is still called, even when applied to them, "restoration." But this restoration is, strange to say, nearly or quite opposite in character to that adopted in the case of an old Gothic church. Everything is reversed. The walls of the Gothic building are carefully and thoroughly scraped of their coatings of wash, and the bare stone brought to sight; but the walls of the Renaissance church are as carefully and thoroughly coated two and three times with almost solid plaster wash, so thick and heavy and opaque, that the whole surface becomes of one uniform tint, and by no possibility but by breaking away can it be told what the walls are made of, whether of brick, plaster, or solid stone; the very workmen employed to do the work sometimes cannot tell you what the walls are made of. The quaint church of Allhallows the Greater and Less, in Upper Thames street remarkable for its wooden rood-screen, and the "restoration" of which is just completed, exemplifies this; for not only is the whole of the interior of the church coated over in this solid and decorative way, but the whole of the outer porch, and solid stone tower as well, is covered up out of sight with it. It all looks like a bran-new chapel of the very latest possible build. Why should this be, if the stone surface of the Gothic church is a something to have, and to see that we have it, why not the stone-work of this poor Italian building? Stone is stone wherever it is found, and surely it is as good to look at as common colored plaster. But so it is, and it serves to show into what an odd state, things artistic and architectural have fallen. The ceilings, of course, of these churches are similarly treated, and so thickly sometimes is the white-wash put on, that the ornamental details, small mouldings, and small foliage, are almost hidden away altogether by it; all character and modelling is, of course, thus destroyed. It seems, indeed, a thing not a little strange that the work in a Gothic roof should be so carefully cleaned of its wash and coatings of any kind, and the workmanship of it brought to light, while the very same details of ornament, when in a different style, should be as industriously covered over. Professor Cockerell before he commenced the *painting* of St. Paul's, began his work by "yellow washing" in good solid coats the whole of the stonework of the north-east aisle, of course to the almost total destruction of the ornamental details of it, and it was the seeing this deplorable effect of it that probably led him to the yet more fatal expedient of *painting* the rest of the Cathedral —more fatal because harder to scrape off!

We have said that everything is reversed; the Renaissance restorer is the very reverse of the Gothic restorer. Take the wood-work, for instance, the pews, and pulpit, and desk, and communion-table.

In the Gothic church, as all know, it has been the custom to do away with all closed pews, and even a society exists to protest against them, and they have been made to give way to open benches—not always of the most comfortable kind; but in the City church restorations, these pews have been wisely, when the character of the church is taken into account, retained; but instead of all paint and varnish being carefully and industriously cleaned off, wonderful to say, in some instances, the wood-work, though of dark-colored good oak, has been painted and grained in imitation of light-colored oak, and in those instances wherein the real natural wood has been allowed to show itself, the whole of it has been so thickly covered with coats of thick varnish, that it is almost impossible to tell what the wood is, or whether it is wood at all, or only some patented composition, so effectually is the real nature of the natural substance hidden away by the artificial polishing. Wood and workmanship alike go almost out of sight under it.

Has not everything architectural to be yet commenced anew, and is it not a thing for the future to find out the beauty of every natural substance, stone, wood of all kinds, and even metal? Nothing can be more dangerous in the hands of the thoughtless than *varnish*. Like gunpowder and sharp knives, it is a good thing in its way; but give people an unlimited supply of either, and fearful damage must come of it.

In more than one of the City restored churches we could name we will defy anybody to discover the *wood* under the thick coatings of varnish with which it is covered. But, why varnish good dark oak-wood at all? Is it not better to let the natural material show itself? And if there be any practising architect who asks for a way to add to the plain natural beauty of the newly-wrought wood, we can point with confidence to a common briar-root pipe as an example of it. A little oil and elbow-grease only are needful to bring out all the markings and color of the finest or the very plainest of natural woods. Does it not seem a pity that the great problem of architectural and artistic restoration should not be better understood, and that before any more churches are restored, or before St. Paul's Cathedral, which is destined to go through this process, is finally given over to the experimentalists, some public art-body, as the Institute, should not report and perhaps advise upon the modern system.

We must not, even in this slight notice of Renaissance restoration, omit to notice what would seem to be a sort of generally-received restorer's axiom, for we see it everywhere—we allude to the system of painting—where all else is left bare—the architrave, and cornice, and jambs of stone doorways. We speak of this more especially because of the recent painting in this way of the finely-designed small doorway in the north-east aisle of St. Paul's. Why so treated, it being out of the way of visitors and sightseers, it would be hard to say, or what motive there could be in singling it out for painting, and thus throwing it out of the Cathedral harmony. Another fine doorway in St. Paul's treated in this poor way is the doorway in the south transept leading into the vaults or crypt, a singularly unfortunate spot to pitch on for such bright and new-looking work; for no one expects a crypt filled with coffins and dead men's bones, to look new and smart. Such a place must be dismal, and look old and time-worn, and one would have thought that the doorway into it from the body of the church might have been led to harmonize with it, and allowed to remain as it was, and to look old and quiet, if but by way of prelude to the solemn place it led to. But we live in practical and business-like times, and cannot be expected to see poems in architecture!

THE RIVERS OF FRANCE.

From "Engineering."

M. Thomé de Gamond, the French engineer, so well known for the numerous grand projects he has from time to time made public, and whose name has long been connected with the Channel Tunnel scheme, has recently published a treatise upon the running waters of France, which evidence a great amount of labor, followed

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with perserverance during a long series of years. Even in 1832 M. de Gamond proposed to the French Government a comprehensive plan for the utilization of the interior waters of the country. But at that time the spirit of co-operation for the execution of great works of public interest was not developed as it was 15 years later for the construction of railways; the carrying out then of a reform in the régime of the rivers fell entirely on the State. But in spite of the good-will of various people in authority, whom the author had succeeded in convincing, the Minister of Finance, although much taken by the fruitful promises of the project, placed a veto upon its adoption, on account of imperative economical reasons. M. Thomé de Gamond was then obliged to renounce the realization of his plans, but he nevertheless continued to study them out in all their details.

In 1843 a certain public movement towards the pursuit of great enterprises induced the author to present anew his work to the Government. But it was objected that the great project would be entirely obnoxious to the railway interests.

The same under the Republic of 1848, and under the Empire: the Ministers of Public Works successively examined the question, and unanimously praised the perseverance and industry of the engineer, but they all urged the impossibility of carrying out so great a work before the *réseau* of railways was completed.

In 1862 M. Thomé de Gamond brought his project before the public in a series of 10 articles published in "La Patrie" under the title of "The Rivers of France." The engineers, charged with the various hydraulic services of the departments, for the most part approved the simplicity of the proposed plan. This reform appeared to them the more acceptable because it was the practical generalization of methods proved separately and by experience. But the approbation of the engineer was not sufficient to insure the execution of the project, and to-day the author comes forward again to submit it to the consideration of all those who have the prosperity of France at heart, hoping that in the presence of such promising results the spirit of co-operation so fully developed in his creation of railways, will not be wanting for his scheme.

What this scheme is, we may gather from M. Thomé de Gamond's essay upon the required reform in the general régime of the inland waters.

Instability is the principal inconvenience in the actual condition of things. The waters flow in the upper effluents down steep slopes into the great collecting rivers, which generally present but a slight fall. It results from this condition, that the feeding streams situated far up streams empty themselves rapidly, by reason of their velocity in times of flood, whilst the waters accumulated lower down spread themselves over the land, causing frequent inundations. The harvests in the upper plains are then made barren through dryness, whilst the lower valleys of the rivers are flooded. This disordered state of things arises solely from the natural irregularity in the profile of the inclined plane along which the flow of the waters takes place towards the ocean.

The works already undertaken to improve the natural régime, are sufficient to prove the immense resources that could be developed. There are plenty of examples to show the benefits that are to be obtained by the utilization of the rivers, and no inventions are required to put into use these treasures of force and fertilization. It is enough to appreciate and to imitate the results already obtained, in generalizing upon a comprehensive plan applicable to the entire country, the practice undertaken at home and abroad.

M. Thomé de Gamond proposes to suppress the natural profile of the large watercourses which are imperfect, and to substitute for them a series of regular planes in successive slopes. This would be, in other terms, the transformation of the inclined planes of rivers into hydraulic staircases. The full régime would be maintained in those rivers where, in the natural state of things, the water is sometimes deficient, and sometimes in excess. For this purpose the overflow would be regulated by dams for the retention and distribution of the water, and there would descend to the sea only that portion which would be in excess after it had fulfilled all the numerous useful purposes for which it would be destined. Spacious reservoirs would also be established at the higher levels for storing up a portion of the superabundant rain water, to utilize it during dry seasons. These reservoirs

would form lakes some miles in length, and of variable width, enclosed in valleys, and containing water 60, 80, or 100 ft. deep.

The rivers of France, from their source to the sea, would be divided into a multitude of reaches, maintained by weirs, a system well known upon many canalized streams. The régime of outfall being thus distributed among basins at constant levels, it would be easy to regulate the different hydraulic systems according to the available supply, the irrigation of land, the motive power in the various falls, the navigation, etc. The necessary precautions against inundations would be much simplified, and would be reduced to measures partly administrative. Extreme velocities would be suppressed in the river beds, where the slopes were heavy, to be localized carefully in the various weirs, when they would produce immense hydraulic power now lost, to the benefit of every kind of industry. The current being almost entirely on the surface of the water, the disintegration of the banks, and the encumbering of the beds of rivers, would be avoided. At the higher levels floods would be unknown, and the denudation of the ground, so fatal to agricultural property, would cease.

M. Thomé de Gamond gives a general Table of the various rivers in France, classified by their natural basins. Abstracted, this Table is as follows :

Name of Basin.	Area in square miles.	Population in thousands of inhabitants.	Total length of the river in miles.	Mean slope in parts per 1000.	Mean volume of diurnal rainfall in millions of cubic feet.	Mean volume of diurnal discharge into the sea in millions of cubic feet.
Seine	28,605	6,867	9,139	0.95	1,645,615	761,799
Loire	42,604	6,853	20,059	1.23	2,688,130	1,096,170
Gironde	33,503	5,082	17,469	2.86	2,621,060	1,311,359
Rhone	36,506	6,327	10,918	2.28	3,308,774	1,914,530
Rhine	14,183	2,969	5,632	1.03	974,280	269,692
Escant	1,202	1,044	715	0.53	71,094	106, 51
Manche	16,705	4,499	5,094	2.00	1,345,671	293,907
Ocean	18,287	3,181	8,930	0.92	1,430,426	386,676
Mediterranean	10,836	1,462	3,737	3.15	637,906	208,164
Totals	202,431	38,284	81,693	1.52	14,722,956	6,348,958

The total volume discharged into the sea is about 180 milliards of cube metres, corresponding at the rate of 140,000 cube ft. to the acre, to the irrigation of 45,000,000 acres, if the whole of this volume was employed in irrigation. This same volume could furnish by its fall the enormous amount of 12,000,000 of horse power. Both these questions of irrigation and power are studied by M. Thomé de Gamond. He shows that France lacks meadow lands, that she could lay out immense areas to receive irrigation, that by increasing the number of cattle raised more manure would be available for the cultivation of cereals. He calculates that a rent of 16 francs per acre per annum could be obtained for irrigation.

The chapter on motive power shows that there exist in France about 40,000 dams, and that there would be established an equal number of new dams, having an average fall of 10 ft., each able to furnish, after deducting the due proportion for irrigation, a mean force of 40-horse power. Industrial establishments could thus spread themselves over the whole surface of the country under the most favorable conditions, the use of steam would be reduced to very narrow limits, and the exhaustion of coal supplies would become a question for the remotest consideration. It is proposed by the author to fix the rent of each horse power at 72 francs per annum.

Considering, then, the condition of the

present régime, and passing on to review the various means suggested to improve it, M. Thomé de Gamond proposes to raise the level of the outfall of oceanic rivers, very sensibly, 2 ft. for example, by means of a dam interposed transversely across the embouchure of the river. These dams would be monolithic, raised above the beach, and intended to hold back the sea within the limits of its own domain. The sea, spreading out at the foot of these structures, would deposit shingle and sand along its whole length. The volume of water in the river reduced by that amount taken for irrigation, and regulated by the high-level reservoirs, would discharge itself over the crest of the dam, and at low water by sluices.

The access to the great seaports of France would then be improved for ships of heavy tonnage, and the great river harbors would be opened for navigation by transforming the sea channels into vast lakes of fresh water, independent of the sea. The ebb and flow of the tide would be suppressed. An outer port accessible in all winds would receive the ship between two jetties running obliquely from the shore, and they would communicate by locks with the upper level of fresh water. The internal navigation would be found also greatly improved, all the reaches being always kept full of water from their sources to the sea. Great lines of water communication could also be completed, and thus an important auxiliary to the railways would be formed. The maximum level being assured in all the reaches by the construction of the proposed dams, it would only remain to connect the former by locks. It would be necessary to have about 4,000 locks to open a navigable system of more than 18,000 miles, to which would be added the 2,500 miles of imperfect canals France to-day possesses. At the rate of 80,000 francs for each lock, the cost would amount to several hundreds of millions.

Fish culture could be introduced on a grand scale in the improved rivers, and from this source alone, according to the author, an enormous revenue would be derived. It is urged that inundations could be successfully prevented were the proposed measures carried out, thanks to a system of regular discharge, and to the means taken for the storing up of the rain water in the upper valleys.

Up to the present time the various problems which we have thus passed under review have only been worked out independently. Thus there have been executed the necessary works for the utilization of rivers for the supply of cities, for obtaining motive power, for irrigation, and for navigation, whilst in isolated cases the means for defence against inundation have been carefully studied. But nothing approaching a general and comprehensive scheme has ever been developed, and the rivers lose themselves in the sea without being utilized. It is urged that the absence of the spirit of co-operation has hitherto prevented this reform, and it is proposed that in each of the basins named above, a powerful company should be formed analogous to that of the railway companies. These companies would have no cause for demanding State subsidies, because the enterprise would become highly profitable. They would have each the development of the various water services under the control of the State; they would have to pay to Government annually one-tenth part of their receipts; they would possess entire control of the management; and at the end of a concession of a century's duration the whole of the works would revert to the State.

The whole of the expense for 40,000 dams, 4,000 river locks, and 262 marine locks, the acquisition of lands, the construction of irrigating canals and conduits, the buildings, machinery, earthworks, etc., would of course be enormous. The annual receipts derived from irrigation, power of navigation, fish culture, etc., are assumed to amount to 550,000,000 of francs, a sum which would largely repay for the capital invested. Such is the magnificent scheme which M. Thomé de Gamond has once more brought forward. It is a scheme at which he has carefully labored until he has developed its closest details, and the advantageous results anticipated are possibly not overdrawn. But it is to be feared that, even while comprehending the grand development of prosperity that even the partial execution of this project would bring about, public opinion will remain almost indifferent to propositions. And at present, France, having the utmost need of energy in pushing forward in the path of progress, is yet paralyzed in her efforts by the rigid exigencies of necessity.

REPORTS OF ENGINEERS' SOCIETIES.

INSTITUTION OF MECHANICAL ENGINEERS.—The general meeting of the members of this Institution was held at Birmingham.

The first paper read was a "Description of Miller's Cast-Iron Steam Boiler," by Mr. John Laybourne, of Newport, Monmouthshire. This boiler is composed of a series of cast-iron sections, of 2 patterns only, each of comparatively small size, so as to contain only a small quantity of water; those at the front end form a succession of arched tubes over the fire-grate; and the rear sections consist each of 5 vertical tubes, united by a transverse horizontal tube at top and bottom, and placed with the tubes in each section opposite the spaces in the next. The whole of the sections of both patterns are bolted together by flanged joints at the bottom, each section having a communication through the bottom joints with the adjoining sections on either side; and a smaller wrought-iron p pe from the top of each section conveys the steam to a main steam pipe common to the whole boiler. All the joints are protected from the action of the fire, those at the bottom being below the fire level, while the joints at the top are in a chamber above the top of the flue. For the purpose of insuring efficient circulation of the water in all portions of the boiler, the arched sections at the fire end are cast with a longitudinal mid-feather in each leg, by which the ascending current of heated water on the inner side exposed to the fire is separated from the descending current of cooler water on the outer side; and in the rear sections the vertical tubes have an internal circulating tube placed within each, the heated water ascending through the outer annular space, and the cooler water descending within the circulating tube. All the sections of the boiler are left free to expand with the heat, the rear sections being attached together by only a single central joint, and the wrought-iron steam pipes at the top are long enough to allow of yielding to the requisite extent; the arched fire-box sections are attached to the rest of the boiler on one side only, and are free to expand on the other side. No case has occurred of explosion with any of these boilers; and in the very few instances in which accidental fracture of the cast iron has taken place, the only result has been that the water contained in the boiler has flowed out through the crack, without causing any damage beyond putting the fire out. By means of the flanged joints a broken section in any part of the boiler can be readily removed, and replaced by a new one, without disturbing the rest of the sections, which are all duplicates of one another. Specimens were exhibited of fractured pieces taken from the boilers, illustrating the harmless nature of the cracks occurring in the cast iron, and showing also that the quality of the metal remained unimpaired after more than 2 years' working. The boilers are kept clean by blowing off at regular intervals, according to the quality of the feed-water, and any deposit accumulating in the bottom portions is raked out, whenever necessary, by taking off the bottom covers at the ends of the boiler. As the total quantity of water contained in the boiler is small, in proportion to the extent of heating surface, the water level is in some cases maintained at the required height by means of a self-acting feed apparatus, consisting of a hollow ball suspended from the arm of a lever controlling the feed cock; two pipes extending some distance horizontally communicate respectively with the top and bottom of the ball, the former terminating at the high-water level inside the boiler, and the latter at a lower level. As soon as the water level rises and covers the orifice of the upper pipe the steam previously contained in the ball becomes condensed, and a vacuum is formed; and the ball then becoming filled with water entering from the boiler, depresses the lever, and shuts off the feed. When the water level falls again below the orifice of the upper pipe the water runs back out of the ball into the boiler, and a counterpoise upon the lever raises the ball and turns the feed on again. One of these cast-iron boilers has now been at work for 2½ years at the writer's works with complete success, and with an important economy in fuel. Several other boilers of the same construction are also in use at other works, and have proved entirely satisfactory. The particulars were given of a series of experiments made to test the evaporative power and economy of the boiler at the writer's works; and the average duty amounted to nearly 11 lbs. of water evaporated from 100 deg. temperature of feed per pound of Ebbw Vale coal.

The next paper was "On Steam Pressure Gauges," by Mr. Ernest Spon, of London, communicated through Mr. Charles Cochrane. The reliable construction of steam pressure gauges is of much importance in connection with the safe working of steam boilers, a great number of the spring pressure gauges in ordinary use having been found inaccurate, either from defects in original construction or in consequence of their becoming unreliable when in constant use. In the Bourdon gauge, which is the spring pressure gauge that has been the most extensively used for a great number of years, the indication of the pressure is obtained by the employment of an elastic metallic tube, bent to a curved form, which when subjected to internal pressure becomes less curved; and the resulting movement of the free end of the tube communicates motion to an index upon a dial, through the intervention of a lever or a toothed sector and pinion. The elastic tube, however, is liable to become permanently strained by continued use, or by accidental exposure to an excess of pressure; and the indications of the gauge are then no longer correct. In the Schaeffer gauge the pressure is measured by the deflection of a circular corrugated steel plate, fixed round the circumference and bulged in the centre by the pressure, the extent of the bulging being magnified upon a dial by means of a toothed sector and pinion. This gauge, though it has been considered one of the best in use, has a disadvantage in the very small range of deflection of the plate under the pressure, requiring the motion to be very largely magnified upon the dial, whereby any errors are also proportionately magnified. The plate is also liable to be permanently strained by an excess of pressure, and is moreover liable to crack when continually worked. The metal of this plate being very thin, as is also the case with the elastic tube of the previous gauge, its elasticity is liable to be diminished when any oxidation takes place, and error in the indications is then the consequence. The pressure is also measured by the bulging of a circular steel plate in Wallis' gauge but the deflection is increased by the plate being cut into five segments by radial slits; and a thin brass diaphragm or a sheet of vulcanized india-rubber is used to cover the slits on the side exposed to the pressure. The brass diaphragm, however, is found too rigid

to admit of the requisite sensitiveness in the gauge; while the india-rubber is liable to get forced into the slits by the pressure, thereby obstructing the action of the gauge. A solid piston working in a cylinder is supported against the steam pressure by a steel spring in Miller's gauge, and is rendered steam-tight in the cylinder by an india-rubber diaphragm, which is fixed round the circumference between the flanges of the cylinder; the motion of the piston is communicated to the index by means of a short chain, coiled round the spindle of the index, and attached to the arms of a vibrating bow, which is actuated by the piston rod. The motion of the piston is limited to a very short range, owing to the risk of the india-rubber diaphragm getting cut round the edge of the piston with a longer action; and the construction of the multiplying gear for the index involves objectionable complication. In Smith's gauge, which has been extensively used, a steel volute spring is employed, and is acted upon direct by the steam on one side, being covered on that side by an india-rubber diaphragm secured round the circumference to make a steam-tight joint. This spring has a considerable range of action compared with the gauges previously noticed, and being of considerable substance is not liable to be affected in strength by corrosion; the deflection of the spring moves the index by means of a rack and pinion. Three concentric spiral springs, placed one within another with their ends covered by an india-rubber diaphragm, are employed in Silvester's gauge, which is similar in principle to the last one; and the motion is communicated to the index by a rack and pinion. There is, however, an objection to the employment of a rack and pinion for actuating the index of a pressure gauge, on account of the play occurring in toothed gearing; and in Foster's gauge, in which the pressure is measured by the deflection of a volute spring covered by an india-rubber diaphragm as before, the movement of the spring is transferred direct to the index, by means of a stud fixed to the centre of the spring and working in a spiral groove in the spindle of the index. This pressure gauge has been found by the writer to be superior to the other gauges in use, in regard to durability, accuracy, and sensitiveness. The strength of spring employed is proportionate to the limit of pressure to be measured, the total range of deflection being the same in each case. Specimens were exhibited of the various gauges described, and the action of some of them was shown by means of a force pump.

An adjourned discussion followed upon a paper read at a previous meeting, "On the Principal Constructions of Breech-Loading Mechanism for Small-arms, and their Relative Mechanical Advantages." The special features of the Henry and the Soper rifle were pointed out by their respective inventors; and specimens were exhibited of these and numerous other breech-loading rifles in illustration of the descriptions given in the paper. It was remarked that the particular construction of breech mechanism in the Martini rifle, which had at present been selected for the national weapon, was open to serious objection from a mechanical point of view, more especially in the substitution of a spiral main-spring with direct action and short range, in place of the ordinary flat main-spring acting with a variable leverage, the latter having been proved by long practical experience to be completely successful for the purpose. By the use of the spiral spring, the pressure upon the trigger nose at full cock is so greatly increased as to necessitate the addition of an exceptionally delicate contrivance for facilitating the pull-off in firing, and a consequent liability to irregularity in resistance is entailed; but the whole of this objectionable complication is obviated by reverting to the ordinary flat main-spring, and an easy and uniform pull of the trigger is obtained.—*Engineer.*

American Institute of Mining Engineers.—The third and a very successful meeting of the Institute of Mining Engineers has just been held at Troy, N. Y. The members were hospitably received by the citizens, and an address of welcome was given by the Mayor. The principal iron works and furnaces in that vicinity, and at Albany, were thrown open to the inspection of the members; and upon the invitation of the Port Henry Iron Company, they visited the celebrated iron mines at Moriah, in Essex County. The Bessemer steel works of the Messrs. Griswold, the new anthracite-burning iron furnaces below Albany, and the extensive furnaces and rolling mills of the Messrs. Burden were visited in succession.

The sessions for the transaction of business, and the reading of papers, were held in the evenings in the Common Council Chamber, and were well attended by the members and others specially interested in the manufacture of iron and of steel. Most of the communications related to these industries, but there was one very valuable paper by Mr. Eilers (the assistant of Commissioner Raymond in the collection of mineral statistics), upon the Metallurgy of Lead and Silver in Utah and Nevada. Among other papers were the following: Manufacture of Bessemer steel, by Prof. Drowne; Late Improvements in Blast Furnaces, by Prof. Egleston; Iron Manufacture in the Lehigh Valley, by David Thomas, the President of the Institute; Electricity and Mineral Veins, by Prof. Raymond; Efforts to make Iron in Blast Furnaces in Japan, by Prof. Blake; Iron Deposits of Essex County, by Prof. Maynard; Description of Krupp's Steel Works, by Prof. Egleston.

Some or all of these papers will be published in a volume at the end of the year, and will be distributed to the members.

Engineering Society, King's College, London.—At a general meeting of this Society, held on Friday, October 27th, Mr. Hunter, president, in the chair, Mr. Gamble read a short paper on the manufacture of carbonate of soda, describing the manufacture of sulphuric acid, and its use in the preparation of salt cake, or sulphate of soda, from common salt, and the conversion of the sulphate into carbonate. He concluded by enumerating the chief processes lately invented for the improvement of the manufacture.—*Engineer.*

Edinburgh and Leith Engineers' Society.—At the last ordinary meeting of this Society, a paper was read by Mr. Alex. B. W. Kennedy, consulting engineer, on "Marine Propulsion." The paper was divided into two distinct sections: (A) The cause of the resistance to be overcome by a vessel. (B) The methods adopted in practice for proportioning the power to the resistance. Each of these divisions was taken up at considerable length, and treated of in an able manner. Under the first heading, in showing the various resist-

ances—direct and indirect—opposed to a vessel's motion through the water, the author dwelt much on the theory of wave-lines. He showed that every ship must be accompanied in its progress by a wave-crest both at bow and stern, and by a wave-trough amidships. These waves, if once started, would continue of the same size for thousands of miles, and in the case of a ship rightly proportioned would cause no loss of power to produce or overcome them so long as their path of direction remained parallel to that of the vessel In well-designed vessels no other waves were created. The main hindrance to a vessel s progress the author showed to be "eddy resistance" Eddies were produced by the skin of the ship coming in contact with the particles of water next it. The energy absorbed in producing these eddies constituting the real source of resistance in full-sized vessels, Rankine and Wiesbach had deduced formulæ from which the eddy resistance could be calculated with tolerable facility. In the second part of his paper the author laid down the various methods usually adopted for ascertaining the horse-power of engine required to overcome the eddy resistance of any vessel of about the average degree of sharpness of stem and length of stern. The Admiralty formulæ generally used for this purpose he showed to have many disadvantages, as they required the amount of displacement to be known, which was very often difficult to ascertain, while the coefficient which they introduced varied much with vessels of different size and construction. On the other hand, the formula by Professor Galmyden was much more reliable, as introducing a coefficient which was nearly constant for differently built vessels. The author himself had spent much time in making calculations whereby he succeeded in rendering Galmyden's coefficient more nearly constant by taking into account the mean entering angle of the vessel. The author then spoke of the superiority of compound over ordinary engines, while a large number of carefully executed indicator and other diagrams appealed to the eye as to the truth of the results which the writer obtained by calculation, based chiefly on a coefficient of steam efficiency deduced by himself. A paper was also read by Mr. Alexander M. Mackay, the Secretary of the Society. The object of the paper was to expose the present comparatively imperfect state of knowledge on the subject of the resistance to vessels in water, and their consequent most approved forms of construction. Allusion was made to numbers of experiments on frictional resistance; their results were summarized, and some practical conclusions drawn therefrom.

IRON AND STEEL NOTES.

IRON MANUFACTURE IN FRANCE.—Serious attention is now directed in France to the establishment of new works in that part of the Department of the Meurthe which remains to the country, as well as to the great extension of various existing works. We have already noticed the exceptionally favorable opportunities which the peculiar conditions of France now offer to the various iron industries. Although so large a proportion of the mineral districts has been ceded to Germany, there remains, as we have shown, abundance of ore, easily extracted and worked, with coal and coke at low prices from the Department du Nord, and the Prussian basins, together with an ample supply of labor on favorable conditions, and every facility of transport by railway and canal. It is true that easy terms of import have been accorded to the annexed departments for the benefit of their industries, but these arrangements are exceptional and temporary: the annexation will of necessity have the effect of taking away 150,000 tons of iron annually from France, whilst the demand in the country increases each year by about 50,000 tons.

It is, moreover, evident that there will be with reviving industry, a large field for the sale of cast and wrought iron, and that there will be room for highly remunerative enterprise in the mineral districts. That the project we have spoken of will find ample favor, there is every reason to believe; and we have no doubt that English capital will flow into these chanels of assuredly profitable investment.

THE following telegram was received from the Commissoners sent out to America to report on Danks' puddling machine:

"Danks' furnace successful. Construct furnaces for ten hundredweight; squeeze or hammer single ball. Economy and quality satisfactory. Commission well."

The announcement we make above to the effect that the Commissioners sent out by the Iron and Steel Institute to investigate the merits of Danks' Rotatory Puddling Furnace have found the machine successful, will create no small amount of interest among British ironmakers. We apprehend that the brief telegram, received in this country a few days ago would not be forwarded by the Commissioners until they had not only satisfied themselves that the machines were in successful operation in America with the materials available there but that the English materials could also be used in machines without difficulty. We anxiously shall await the detailed report which the Commissioners may be expected to bring with them in the course of a few weeks, as this will, doubtless, set forth under each head of the inquiry, suggested by the Puddling Committee, all the facts connected with the working of the machine puddler. The telegram, however, is highly suggestive, and opens up a prospective revolution in the finished iron trade. Danks himself spoke of furnaces manipulating from 600 lbs. to 800 lbs. of iron. The Commission advise the construction of furnaces to puddle over 1,100 lbs. of iron, and assert that this large mass can be hammered or squeezed into a single ball. This seems to indicate that the iron is brought out of the machine in a much more homogeneous and purer state than from the ordinary puddling furnace. It will be readily seen, that in addition to the machine puddlers, the appliances for hammering and rolling the large puddled blooms will have to be on a far larger scale than those at present in use. Hence, those who take up the revolving puddling furnaces must be prepared to reconstruct their forges entirely. The Commissioners add that economy and quality are satisfactory. This we take it to mean that the consumption of fuel, yield of iron, and labor required in working the machines, produce, combined, a marked economy

when contrasted with the existing methods; also, that the iron produced is in quality satisfactory. If we may assume from the telegram that the machines have been found successful in manipulating English pig iron, when fettled with the materials available in this country, and that the results have been satisfactory to the Commissioners, we may reasonably conclude that the question of machine puddling is virtually settled. When the detailed report comes to hand, it will doubtless contain many suggestions which those who adopt the furnace in this country will do well to consider; hence, we do not suppose that the information now received will be thought sufficient for any one to proceed upon. As far as we can gather, there are several details in connection with the machine and with the squeezer of Mr. Danks, that may be improved by English engineers, and that would be so improved by Americans as they become better acquainted with the machinery. In the course of a short time the patentee himself will be back in this country, when he will be able to advise on all matters connected with his system. The sum fixed by Mr. Danks as royalty for the use of his machine seems moderate enough—2s. per ton. We expect to find that he will not have altogether plain sailing in maintaining his patent rights. The rotatory principle of the machine is not new; but we understand that there are several points upon which the validity of the patent rests, so that Mr. Danks asserts that he is safe. The fact that a considerable number of machines are working in America, and are paying royalty, would seem to indicate that the patent is good; or its weakness would have been discovered before this in America, as nearly every invention of importance connected with the iron manufacture is protected in America, as well as in this country; and Mr. Danks must have fallen foul of some of these before this, if his position had not been well founded. This, however, is a matter for the patentee to put right. The sums involved, even at a low royalty, are so large that manufacturers and patentee may be expected to look very keenly after their respective interests. The Iron and Steel Institute has done good service to the iron trade by the energetic action it has taken in this matter, and has by this means given a further proof of its usefulness to the trade generally.—*Iron and Coal Trades Review.*

IRON TRADE OF GREAT BRITAIN.—The total amount of pig iron exported from Great Britain to all countries during the first 10 months of the present year amounted to 900,911 tons against 641,678 tons during the corresponding period of the previous year. Of this quantity the United States took this year 156,757 tons against 97,586 tons last year, an increase of 59,171 tons or 60 per cent. During the month of October we imported 24,696 tons, about double the quantity imported in October 1870. Of bar, angle, bolt and rod iron, which in the Board of Trade returns are not separated, the importations in the 10 months above designated reached 51,967 tons against 38,354 tons in the previous year, an increase of 13,613 tons, or 35 per cent. In the month of October we imported 4,522 tons, a slight falling off as compared with the same month last year. The exportations of these classes of iron from Great Britain to all countries amounted to 293,021 tons. Of railroad iron, Great Britain exported 846,606 tons, of which 441,709 tons were shipped hither. We thus see that the United States is a better customer for British rails than all other countries combined. In fact the exportations to other countries generally show a falling off as compared with last year's figures. Russia, for instance, took but 75,028 tons this year against 204,005 last year. The shipments to Germany, Holland, Spain, Austria, Chili, India, all show a marked falling off. The shipments to the United States during the month of October, reached the enormous aggregate of 82,174 tons, exceeding the whole quantity made in this country in that month. Of hoops, sheet boiler and armor plates, we imported 35,553 tons against 34,430 tons last year, a slight increase. Of old iron for re-manufacture Great Britain exported 119,899 tons, and although the countries to which this was sent are not enumerated in the returns, we presume that at least 90,000 tons were shipped to the United States. Of steel, not including Bessemer steel rails, we imported in the 10 months 16,863 tons, against 13,910 tons last year. More than half of the steel shipped from Great Britain is sent to this country. We commend the above facts to our members of Congress, and hope in consideration thereof, they will be slow to adopt a policy that will compel us to obtain from abroad all of the iron required by our busy people.—*Bulletin of Iron and Steel Association.*

RAILWAY NOTES.

RAILWAYS IN AUSTRALIA.—The consumption of railway iron in Australia and New Zealand has not made any very great progress of late, having amounted to August 31 this year to 11,382 tons, as compared with 6,023 tons in the corresponding period of 1870, and 15,827 tons in the corresponding period of 1869. Possibly the falling off observable, as compared with 1869, may be recovered before the end of the year, but still rails and railways do not appear to have made any very great advance in Australia and New Zealand. The aspect of affairs is, however, now of a more promising character than at any former period, and a considerable length of railway will probably be constructed in the course of the next decade. It is easy to see why more has not been done in the past. The railway system is still not 50 years old, and it is little more than 30 years since it became a power in modern society. It is only 20 years, again, since our railway contractors, engineers, and capitalists began to push afield, and the principal colonies which have engaged their attention have thus far been Canada and India. Now, however, that Australia and New Zealand have accumulated between them a white population of about 1,800,000, and now that the foundations of young empires have been laid at the Antipodes, we may expect to witness a more tangible advance in the matter of railway construction. At the same time we must not lose sight of the fact that the industries which have thus far been developed in Australia are, to a great extent, of an agricultural and pastoral character. Agricultural industry, of course, stands in comparatively little need of railway communication. Moreover, although the

Australias now boast a white population of 1,800,000, it is scattered over an enormous area, and distributed over 7 colonies, some of them divided by great seas from Australia proper—New South Wales, Tasmania, Western Australia, Victoria, South Australia, New Zealand, and Queensland. This scattering of a still sparse population is, of course, a great drawback to the development of Antipodean railways.

Nevertheless, there is more stir just now in the Australias about railways than at any former time in their history. Thus a bill has been brought into the Parliament of South Australia for the construction of a line between Adelaide and Glenelg. The traffic on the existing lines of South Australia has sensibly improved this year as compared with 1870, which was a period of depression for the colony. Preliminary measures have been taken for the construction of a railway between Waitaki and Moeraki, in the province of Otago, New Zealand, and the general government of that colony has consented to carry the Clutha Railway somewhat further. The construction of a tunnel upon the Duneden and Port Chalmers line, at a point termed the "saddle," has been proceeded with of late day and night. Operations on the line, which is of no great length, are also being pushed on generally with much vigor, the necessary capital having been lately raised in England by debentures negotiated through the medium of the New Zealand Loan and Mercantile Agency Company (Limited). In Victoria there has especially been a large measure of railway activity—a matter not to be wondered at when we find that mechanical industry has now attained such a stage of development in the colony that the Colonial Government has just been enabled to accept a tender delivered by a Ballarat firm for 10 locomotives at £2,900 each. In New South Wales, the permanent way of the western line has now been laid to a point 101 miles from Sydney, and only 11 miles remain to be laid to complete the Northern line to Murrurunde. In Tasmania a contract for the construction of a main line railway from Launceston to Hobarton has been signed by the Governor, Mr. Du Cane, and has been witnessed by the whole of his ministers; so that the project, which is obviously fraught with important consequences to the colony, may now be expected to proceed to its ultimate stage of development. The capital for the line will, probably, be found by a British company on the faith of a guarantee of interest given by the colony. In the province of Auckland, New Zealand, the construction of a line, which is to connect the head waters of the Waitemata on the east coast with the vast inland sea of Kaipara on the west, has at length been commenced. In the province of Nelson, New Zealand, surveys for a railway from Nelson to Fox Hill have been made, and the plans are now in Wellington. As part of a through line to Westport and Greymouth, such a work would be of the highest possible advantage to the province, and, indeed, to the whole colony. All these details, taken together, tend to the conclusion that the demand for railway-iron, although sluggish at present, will increase in the Australias.

WORKING RAILWAY INCLINES.—Description of Brake Drums and the Mode of Working them at the Ingleby Incline on the Rosedale Branch of the North-Eastern Railway. Abstract of a Paper read before the Institution of Mechanical Engineers at Middlesbrough, by Mr. John Haswell.—The Ingleby Incline is used for the conveyance of ironstone from the mines near Rosedale Abbey, being a portion of the line. It is nearly a mile in length, with a gradient of 1 in 5¾, the steepest being 1 in 5. Loaded trains descend the incline, drawing up at the same time the empty trains, a passing place for the two trains being made in the middle of the length of the incline, by a short double line, and the rest is only laid with three rails, the centre one being common to both up and down trains. The incline is worked in the usual manner of steep mineral inclines by means of a pair of brake drums keyed upon a horizontal shaft, and situated at the top of the incline. The descending train of loaded wagons pulls off the rope from one of the drums, and winds up that on the other, thereby drawing the return train of empty wagons up the incline. Speed is controlled by powerful brakes upon the drums, controlled by a hand winch. The peculiarity of the brakes is the use of cast iron. The drum barrels are 48 ft. diameter, and 4 ft. 8 in. long, made of cast iron 1½ in. thick, and put together in four segments, which are bolted together. Chipping pieces are cast into the face of the flanges, and the segments are fitted so as to form the circumference of the winding barrel with complete accuracy. The wrought-iron brake straps extend round each side of the drum. They are lined with cast-iron brake blocks, and are bored out to fit the corresponding turned blocks on the rim of the drum. The two brake drums weigh together 68 tons, and the shaft carriages and brake segments about 26 tons. The ropes are made of steel wire, each 1,650 yards long, and 5 in in. circumference, weighing 8 tons. The rope end is taken through a hole in the side of the drum barrel, and wound two or three times round the shaft, and secured by a loop knot. A tail chain 12 yards long is attached to the other end, with riding chain 2 ft. long for the purpose of disconnecting the rope and tail chain when the rope is tight. At the top of the incline are a series of pairs of inclined lateral chocks, fixed at intervals between the centre of the rails of the loaded wagon line; these chocks are pressed outward against the wheels of the wagons, to check the speed of the loaded wagons until the drum rope is attached to them. The average loaded train weighs 52 tons, and the unload does not exceed 25 tons. Each run on the incline occupied three minutes, so that the speed of the train is 20 miles an hour. In ordinary working, 200 wagons are run down per day of 12 hours, carrying 1,600 tons of ironstone. These brake drums have now been at work about 10 months, and superseded 2 smaller drums of 14 ft. diameter, which had been working about 10 years. The smaller drums were fitted with brakes of wrought iron and elm wood. These required renewal every 5 weeks, at a cost of £20, and thus a saving of £200 per annum is effected by introduction of the cast-iron surface to the drum and brake.—*Am. Railway Times.*

ENGINEERING STRUCTURES.

PROGRESS OF THE ARTESIAN WELL IN BOSTON.—The work of boring the well was begun in the latter part of the month of March last, and has been going steadily forward up to the present time, the progress made being from 1 to 15 ft. each day, at a cost of $15 per foot, and as the well has al-

ready reached the depth of 1,000 ft., of course the cost already foots up $15,000, and how much more it will take is a matter of uncertainty; but even should it cost $30,000, the company would save the amount in 3 years, and have their future supply at a merely nominal price.

In boring the well the drill has passed through a variety of strata, which would be of interest to the geologist—black shale, slate, quartz, white quartz, intermixed with shining and glistening ores, and a sort of honeycomb rock, indicating the action of the tides or water. Yesterday the drill was passed through a black shale stone, and this morning it struck a dark blue stone nearly as hard as adamant.

At the depth of 80 feet they struck a ledge, and they are still at work in it, occasionally finding a thin stratum of clay. At this depth they also found water, which furnished a supply of about 50 hogsheads an hour, and pumping it out at that rate for 15 min. only lowered it 6 in. in the 5-in. bore. Not being satisfied that this would give them water enough for their works, they still kept on through the ledge to the depth of 140 ft., or 220 ft. from the surface, when they again reached water in the midst of the ledge, which now rises to within 8 ft. of the surface.

The well is now over 1,000 ft. in depth, 900 ft. of which are through solid ledge, varying of course in hardness according to the strata, but never softer than an occasional layer of slate and honeycomb stone. When the work was first commenced, a drill would last 36 hours without sharpening; now the same kind of a drill will only last one hour.

The diameter of the bore is 5 in.; the drill is 4 in. across. The drill and iron shafting which connects it weighs now 1,200 lbs., and the rope by which it is lowered weighs 900 lbs. The machinery used for driving the drill is similar to that used in the oil regions of Pennsylvania.

The power is furnished by a 16-horse power engine, with a walking-beam of 36 in. stroke, at the rate of about 30 strokes per minute. It is the intention of the company to keep the drill at work until they obtain a sufficient volume of water for their use, unless their money gives out, or the drill goes through on the other side.—*Am. Railway Times.*

NEW BOOKS.

PLATTNER'S MANUAL OF QUALITATIVE AND QUANTITATIVE ANALYSIS WITH THE BLOW-PIPE. By PROF. T. H. RICHTER. Translated by H. B. Cornwall, A. M., assisted by J. H. Caswell, A. M. New York: D. Van Nostrand.

One of the most observable features in the history of the progress of education in this country is the rapid strides which science is making both in the lower and higher grades of instruction. Nothing is more noticeable, to those who are in the habit of either attending or delivering lectures in this country, than the eager desire both on the part of the wealthy and the poor to be considered as the possessors of some knowledge which may be called scientific, either because it is not usually possessed by their associates, or because the attainment of it leads to a real or fancied solution of some problem of more or less importance in the economy of life. This eager desire after scientific knowledge can hardly be said to be peculiar to the United States, for we find it in other countries; but it is highly characteristic of our people. The list of lectures to be delivered during the winter months in many cities and towns of the United States would rival in variety of subjects that of almost any University. The ability with which the subjects are treated varies greatly; but the variety of topics, and the more or less systematic arrangement of them, show an eagerness after general knowledge which is ever on the increase, and has already produced a very perceptible influence on our intellectual culture.

Nor is this true of what is called popular science alone. The rapid advance in the higher departments of science made in most of our institutions of learning shows a most extraordinary increase of life and vigor. It has, within the last ten years, remodelled the Sheffield School at New Haven, founded and brought to a very prominent rank the School of Mines of Columbia College in this city, and caused the Stevens Institute of Technology of Hoboken to be liberally endowed by a single individual. As we look back twenty years at the very doubtful standing which was then allowed to science in our prominent universities, we scarcely know whether to admire most the liberality which has founded these and similar scientific institutions, or the very high position which they have attained for themselves, and to which they have helped to raise science in this country.

The energy required for the foundation of such institutions necessitates the expenditure of so much vital force, that it is not surprising that we do not find the same large number of original works on various scientific subjects by American authors, that we find published in the older countries of Europe. While it is perhaps true, that there never has been a country which in so limited a time has furnished a greater number and variety of original researches, which have both aided theoretical investigations, and added so largely to the sum of human happiness, we have produced but few books which occupy prominent places in science. We point with pride to the Mineralogy and the Geology of Dana as contributions to science of which we may boast, but it must be admitted that these and a few other American works are exception productions in any country, and it would perhaps not be reasonable to expect of us, a nation with everything to create and to found, that we should dispute the palm with older nations, whose work of foundation was done long ago, and who have grown with the growth of science, while our institutions must spring into existence fully armed and equipped.

If, however, we do not produce so large a number of original works on science as older countries, we adopt into our language most of the works of high excellence, published in other countries. Its American translator has made "Wiesbach's Mechanics" almost as much a part of the English language as if it had been originally written in English. It is not without gratification that we notice that our translators of foreign works are frequently not content with rendering into English the text of the original. Translations with us, are often really new editions of the works, with modifications and improvements by both author and translator, adopted by mutual consent, so that the translation at the time of its publication, is really an edition in advance of the original, the author being, in many cases, quite as eager, or

perhaps more eager to claim the translation as the original work.

A most remarkable instance of the greater value of the translation over the original work is presented in the recent publication of Richter's "Plattner's Blow-pipe Analysis." This work has, from the date of its first publication, been recognized as the only complete treatise on the subject. The fourth German edition appeared in Leipsig in 1865. The English translation just published with the co-operation of Professor Richter, is really the fifth edition of the work, since it is much more complete than the original. It has been brought by the author and translator, up to the present time. Nor can it be said to be an ordinary translation. The German has not only been rendered into good English, but the translator, and the gentleman who assisted him, are both former pupils of Professor Richter, both skilful blow-pipists, and have had several years' experience in this method of assaying ores and metallurgical products in the country. They were both engaged in giving instruction in the subject while the translations were being got ready for the press. The work has not only been brought up to the present time, but a terminology has been adopted, which is familiar to American students. The indexes to substances have been made much more complete and a general index added, which does not exist in the original. The work is therefore, not only more complete, but better adapted to the use of the American and English students, than the last German edition, and it must be considered as a very valuable edition to our scientific literature.

While Prof. Richter must be congratulated for having had such able translators of his work, American and English students of science are greatly indebted to the translators and publishers for having placed this remarkable book within their reach.

Pp. 1 to 56 give the description of the apparatus and reagents required for making the various tests and assays. On pp. 31-35 will be found the description of the latest apparatus invented for estimating the values of gold and silver buttons which are too small to weigh. Pp. 59-394 give the rules for blow-pipe analysis, commencing on p. 59 with the general rules to be observed. Pp. 112-394 contain a very large number of methods for examining both metallic and non-metallic substances. On pp. 380 to 394 a number of examples of methods for mixed substances are given.

These methods and examples contain every possible case, from a simple chemical salt, to those very complicated substances known as *spiess* and furnace *sows* or *bears*. The methods are so accurate, that with practice, sufficient skill may be acquired to determine with the blow-pipe the constituents of a complicated substance, with almost as much precision as by the ordinary wet method. Unfortunately there are few persons who are willing to give the time necessary for accurate determination with the blow-pipe, and no doubt the impossibility which has until recently existed, of obtaining in this country either the instruction or the instruments, has retarded the general use of the blow-pipe. The translation of this work will make it no longer a matter of surprise, that students in an examination can determine twenty-three substances in three mixtures as a test of their skill in blow-pipe manipulation.

The third section of the work, from p. 397 to the end, is devoted to the description of processes for the quantitative assay of ores, minerals, and furnace products. It will be a matter of surprise to those who do not know to what perfection these processes have been brought, to learn, that ores can be assayed with an outfit that can be carried in the pockets, and so accurately as to warrant the results being relied on in commercial operations. There are a number of metallurgical works in Europe and a few in this country where the blow-pipe is used in connection with the ordinary wet and dry assay, the results being often in favor of the accuracy of the blow-pipe. For ordinary purpose of field work in exploration, the possibility of having a complete outfit including the balance and reagents in such compass, that it can be carried in the hand, makes it a most convenient adjunct to all outfits for parties exploring new fields. There are assays in which the blow-pipe method has a real advantage over the old methods. Thus the assay of a mixture of cobalt and nickel can be made by the blow-pipe in less than two hours time, including the preparation of the assay, and quite as accurately as in the much longer and tedious wet method. The assay of gold and silver and most of the other metals can be made within an hour.

The amount of skill and practice required to make these assays is not greater than that required for ordinary assaying. They can be made anywhere, and require no costly installation. One reason why these assays have not come more into use is that there is an idea that continued blowing is injurious to the lungs. This is not true. The muscles of the cheeks alone are called into play and exercise. There need not be, and there ought not to be, any strain upon the lungs. In fact if there was any strain upon the lungs it would be quite impossible to make an assay. A person using the blow-pipe *must* breathe through his nose. The communication between the mouth and the lungs is completely closed except at the moment when the mouth is filled with air, and that is an instant of time. The supply of air to the lungs *must* be made through the nose. This is the proper and natural means of supplying the lungs. There is no more reason why the lungs should be strained by twenty minutes' use of the blow-pipe than by walk in the open air, of the same duration, with the mouth closed, as it should be, the supply of air to the lungs coming through the nose.

The instruments required for the examination of substances of the blow-pipe are simple and inexpensive. They have, as yet, not been easy to procure, but it is to be hoped that some American manufacturer may be induced to make them, at such a price as will place them within the reach of every student. The instruments required must be carefully made. With a large part of the instruments offered for sale, it would be impossible to perform the most ordinary blow-pipe experiment properly, and with many not at all. This is owing partly to the fact that neither those who make, nor those who sell them, understand their use. Up to this time we have been dependent on Lingke, of Freiberg, for the best apparatus made. It is to be hoped that our great superiority in mechanical skill, will enable some manufacturer to produce the instruments in this country, at such a price as to be within the reach of all.

THE WORKMAN'S MANUAL OF ENGINEERING DRAWING. By JOHN MAXTON. Lockwood & Co. For sale by Van Nostrand.

This book supplies what has long been wanted,—a good, practical, and low-priced treatise on engineering drawing. Commencing with a description of how a drawing office should be fitted up, Mr. Maxton proceeds to impart to the draughtsman a variety of valuable information concerning the materials and tools he will require to make use of, such as drawing-boards, squares, instruments, scales, colors, paper, etc. He next tells him how to prepare his paper and how to ink in his drawing, how to shade and color it, and how to border it and cut it off the board when finished, each of these subjects being treated in a separate chapter. In addition to this, there are chapters on practical geometry, projection of shadows, delineation of the slip and path of the screw propeller and paddle-wheel, on drawing tracings, for the use of engravers and photographers, and on diagrams for lectures, besides an appendix containing notes on architectural and ship drawing, and on perspective and isometrical projection, as well as on sizing, varnishing, etc. The whole is illustrated by a number of plates and by nearly 350 woodcuts.

Probably the best chapter in the book, though all are excellent, is that on the projection of shadows; commencing with the more simple shadows, such as thrown by columns, etc., Mr. Maxton proceeds, by carefully graduated steps, to show how those on various curved surfaces may be found, and his exposition of general principles is here so clear that the most inexperienced draughtsman will be able, by the aid of this part of the book, to accurately determine any shadows required in ordinary engineering drawing. The chapter in the appendix on the detail drawings of steamships also embodies many valuable hints. Although Mr. Maxton's book is intended chiefly for the instruction of students and working engineers, even accomplished draughtsmen will find in it much that will be of use to them, and a copy of it should certainly be kept for purposes of reference in every drawing office.—*Engineering.*

HANNA'S COMPLETE READY RECKONER. By J. S. HANNA. Philadelphia: J. B. Lippincott & Co. For sale by Van Nostrand.

This set of tables is of convenient size for the pocket, although the type is of good size, and the numbers liberally spaced.

The book is designed for the use of lumber inspectors and surveyors.

A TREATISE ON ENGLISH PUNCTUATION. By JOHN WILSON. New York: Woolworth, Ainsworth & Co. For sale by Van Nostrand.

This is without doubt the best treatise to be found on this subject. It is not a new book, this being the 20th edition; but this fact testifies to its widespread use.

Writers, printers, proof-readers, and copyists find in Wilson's work a valuable aid to their labor. The outward dress of the present edition is better than is usually afforded to books which are presumably in frequent use.

AN ELEMENTARY TREATISE ON STATICS. By J. W. MULCASTER, F. R. A. S., Military Tutor. London: Taylor & Francis. For sale by Van Nostrand.

This is a good book, without any of that attempt at cramming, too common now in our elementary text-books. It is calculated to give the reader a good grasp of the elements of Statics. It goes over the usual ground, states and proves the principles well and clearly, and contains in each chapter a numerous and excellent series of examples. These examples consist of "graduated and classified groups of problems each involving distinct statistical principles." These, the author says, he finds, and our experience entirely agrees with his, make "an impression on the student's mind, otherwise not attainable with problems indiscriminately taken." We gather from the book that it is the production of a good and practical teacher.

MINUTES OF PROCEEDINGS OF THE INSTITUTION OF CIVIL ENGINEERS, WITH ABSTRACTS OF THE DISCUSSIONS. Vol. XXXII. Session 1870-71. Part II. Edited by JAMES FORREST. London: Published by the Institution.

If we were inclined to congratulate the Institution of Civil Engineers upon any especial feature more than another in their last volume of "Minutes of Proceedings," it would be upon the admirable diversity of subjects which are treated therein. It is not uncommon in serials of this character to find occasionally a particular tone pervade the whole volume. It is either too mechanical, or too much of the contents are devoted to civil engineering alone. Again, one branch of the profession may be represented in so prominent a manner as to leave others comparatively in the shade. But in the present issue, not only are the recognized and time-honored subjects, such as piers, harbors, bridges, cement, concrete, and other collateral topics of professional interest and practice discussed, but the most modern branch of engineering is brought into notice by a paper relating to the sewage of towns. The volume opens with a couple of communications, the first of which has for its object the determination of the best form of the Archimedian screw pump, and its effect when laid at different angles of tilt to the horizon; while the second is devoted to the history and construction of centrifugal pumps.—*Engineer.*

THE CIVIL ENGINEER'S POCKET-BOOK. By JOHN C. TRAUTWINE, C. E. Philadelphia: Claxton, Remsen & Haffelfinger For sale by Van Nostrand.

Mr. Trautwine's former table book served so good a purpose among the field engineers of this country, that he is already favorably known to the engineering profession.

The present book embraces formulas and tables relating to every subject which comes within the scope of an engineer's labors. Knowing the author's care and skill in such compilations, we should employ these tables with confidence.

Of the treatises upon various engineering topics with which the book also abounds, and wherein the author assumes the office of instructor, we cannot write at greater length until we have examined more leisurely.

A COMPLETE COURSE OF PROBLEMS IN PRACTICAL PLANE GEOMETRY adapted for the use of Students preparing for the Examinations conducted by the Science and Art Department in First, Second, and Third Grade "Practical Geometry." By JOHN WILLIAM PALLISER, Second Master and Lecturer of Geometrical Drawing at the Leeds School of Art and Science. London: Simpkin, Marshal & Co.

So long as Euclid was regarded as the only text-book on geometry it is not to be wondered at that a knowledge of that art should have been so little disseminated among our artisans and workmen. Outside the doors of schools and colleges there was little time and less inclination to arrive at plain and simple results by following a course of reasoning, demanding, in numerous instances, much needless verbiage and unnecessary trouble. Although no learner should study in the dark, yet it cannot be denied that, in cases where the student is engaged all day in some occupation, the capability of practically solving a geometrical question as briefly as possible is of more value than an intimate theoretical knowledge of the nature of the process.

A working man may consider himself perfectly satisfied with being able to trace out a parabola or an ellipse on paper or a platform without knowing anything about the equations to the curves. Recently many text books on geometry have issued from the press, the aim of which has been to impart in a practical manner the principles of this essential art. Among those which unquestionably fulfil their object may be quoted the little volume before us. Each proportion is numbered separately, prefaced by a clear, terse enunciation, and the directions for solving it given in as condensed a mode as the example admits of. One especially commendable feature of the work is the excellent manner in which the diagrams are arranged. As a rule, in treatises of this description they are drawn on too small a scale, which renders the following of the working lines by the student a very difficult matter. This mistake has been altogether avoided by the author, who has had the diagrams drawn to a large scale, with bold lines so as to be readily distinguishable. The book is intended to serve as a guide to those who intend to be candidates at the Government examinations, and we can only observe that if they should not pass in this particular subject it will not be the fault of Mr. Palliser's treatise.—*Engineer.*

MISCELLANEOUS.

HIRSCH'S PATENT SCREW PROPELLER.—We make the following extract from a printed report of Ernest Voss (engineer), of the performance of Hirsch's Patent Screw Propeller on steamship Prins Van Oranje, during her trip from the Clyde to Holland:

"The performance of the S. S. Prins van Orange and her engines during the voyage from the Clyde to Nienwedeep will, at the first glance, be perceived as favorable, when it is observed that the whole voyage from the Clyde to Nienwedeep only lasted 74 hours, namely, from the 8th July, 6.30 P.M. till 1 th, 8.3 P.M., when we arrived on the roads of Nienwedeep. The distance run is 800 miles, and taking into account the stoppages for putting pilot on shore, and making soundings, besides the time lost in going with half engine-power on account of a dense fog at the north of Scotland, it will be seen that the average speed of the ship reached the considerable height of 11 knots per hour.

"The vessel had a mean draft of 16 ft. 1 in. having an immersion of 15 ft. 6 in. forward, and of 16 ft. 8 in. aft, which of course is only a light draft, and is no doubt in favor of speed, as the midship section as well as the wet surface of the ship, the factors of resistance, are accordingly less. But at the same time we must not lose sight of the fact, that at a draught of 16 ft. 8 in. aft, the propeller is not perfectly immersed; the blades project nearly a foot over the water's surface, so that the propeller cannot utilize the full effect of the power transmitted by the engines.

"The coal consumption for the whole voyage was 72 tons, or a little less than 24 tons per day, which means 1 ton per hour.

"According to indicator diagrams taken during the voyage the engines developed a power of 1150 H P., and taking this into consideration with the coal consumption, it shows that the engines used less than 2 lbs. per indicated H P. per hour, which is certainly a most satisfactory result. For further demonstration of the comparative splendid performance of ship and engines, I wish to give the co-efficient according to the following formula:

$$C = \frac{V^3 \times m}{P}$$

where V is velocity of ship in knots; m = midships area (548 sq. ft.), and P the indicated horse-power; C the coefficient, which is variable for different ships. For mail steamers the coefficient is considered as very satisfactory at 70. In our case I find it to be 631, which I think is a very good result."

The Prins Van Orange and her sister ship Willem III. were built by John Elder & Co., the latter differing only in her propeller, which is of the common kind.

The following figures, placed in juxtaposition, will give a comparative view of the voyages of the two vessels from the Clyde to Holland, and as a consequence, also an estimate of the relative performance of the screw propellers fitted respectively to these vessels:

	Willem III.	Prins van Orange.
Draft of vessel—mean	18′ 2″	16′ 1″
" " forward	16′ 9″	15′ 6″
" " aft, for immersion of screw	19′ 6″	16′ 8″
Immersed midship section	628	548
Distance run in miles	840	800
Duration of voyage in hours	84	74
Total coal consumption	81	72
" " reduced to 800 miles	77	72
$C = \frac{V^3 \times m}{\text{coal consump.}}$	8156	10130
Kind of propeller	Common.	Hirsch's Patent.
Pitch of "	21	23
Revolutions of ditto per minute	57	53
Slip of screw per cent	15 2	8.6
Speed of ship in knots	10	11

SOME time has passed since anything was heard of measures to be taken for checking the course of the Tiber. A commission has been deliberating on this subject since last winter, and has only

lately presented its report. The following are the principal recommendations it makes:—(1) To reduce the arches of the bridges, so as to give freer course to the river when swollen (a system adopted in the construction of bridges over the Po and the Adige); (2) to clear out the bed of river, removing all the rubbish of centuries; (3) to cause all the sewers of the city to flow into one common sewer on either side of the river, which *cloacæ maximæ* are to be carried out to Santo Paolo; (4) to construct a Lungo Tevere (embankment) similar to that of the Lung' Arno of the Thames in order to check and guide the stream and offer a promenade for the public; (5) to divert the course of the Tiber. It is proposed to commence operations near the Ponte Molle, and carry the river round behind St. Angelo, and nearer the church of St Peter. The report has not yet been approved and whether projects of so vast a character will ever be accomplished is doubtful—at all events a long time must elapse before this can be done.

Weather Signals of United States Signal Service.—The signal is a square red flag, with a square centre of black, for denoting danger by day, and a red lantern to denote danger by night. It is highly important for the public fully and at once to know, that the Signal office will display only one signal, and that one signal will be elevated only in the case of probable danger There will be no safety signal.

We give below, however, the official text, which, if carefully weighed and pondered, can leave no uncertainty in the mind of any one, as to the meaning and use of the signal.

The Cautionary Signal.—The cautionary signal of the Signal Service, United States army—a red flag with black square in the centre by day, and a red light by night—displayed at the office of the observer, and other prominent places throughout any city, signifies:

1. That from the information had at the Central Office in Washington, a probability of stormy or dangerous weather has been deduced for the port or place at which the cautionary signal is displayed, or in that vicinity.

2. That the danger appears to be so great as to demand precaution on the part of navigators and others interested—such as an examination of vessels or other structures to be endangered by a storm—the inspection of crews, rigging, etc., and general preparation for rough weather.

3. It calls for frequent examination of local barometers, and other instruments, by ship captains, or others interested, and the study of local signs of the weather, as clouds, etc., etc. By this means those who are expert may often be confirmed as to the need of the precaution to which the cautionary signal calls attention, or may determine that the danger is overestimated or past.

This red flag or red light known as the cautionary signal, is displayed when the information in the possession of the office induces the belief that dangerous winds are approaching.

This term, dangerous winds, has a meaning varying somewhat with the locality in which the winds occur. Thus, the severe gales of the Atlantic Ocean, which sometimes attain the hurricane velocity of 50, 60 or 70 miles an hour, are seldom equalled on the lakes. But on the lakes, where the sea room is limited, winds that are reported from the lake coast as "brisk" (i. e., from 15 to 25 miles an hour, in which a ship on the ocean would carry all her canvas,) frequently become dangerous to navigation. Moreover, it is important to remember, also, that the direction of the wind often determines whether it is to be dreaded. Experience demonstrates that most danger is to be apprehended when the wind is blowing on to a lee shore. The cautionary signal might, therefore, be properly expected only for ports thus threatened. For inland, and well-sheltered points, as Baltimore and Philadelphia this distinction cannot be easily made. It has, therefore, been decided that the cautionary signal shall be hoisted whenever the winds are expected to be as high as twenty-five miles an hour, and to continue at that velocity for several hours, within a radius of 100 miles of the station.

Comparative Efficiency of different kinds of Boiler Plates for Steam Generation: We find in a late number of the "Scientific American" a a valuable report on the above subject by Messrs. Whelpley and Storer of Boston. We copy the following:

"None of the various causes which engineers have assigned for the wide differences in the evaporative powers of boilers have seemed to be sufficient and conclusive; and some other important element of variation has long been suspected by those who have given thought to the matter.

In order to discover this hitherto unknown cause, a series of experiments was made, based on the supposition that the conditions which affect the conducting power of a metal for electricity—alloys and impurities—would, perhaps in equal degrees, affect its power for transmission of heat.

"It was evident that all previous estimates of comparative values of fuels, modes of firing, and styles of boilers (the universally recognized causes of variation), would be subject to careful revision if it could be demonstrated that the most important source of error had hitherto been overlooked. The accepted standard results would become valueless.

"Nine pieces of boiler plates of different brands were selected for the purpose of the experiment; they were of uniform thickness (5-16ths of an in.). Some of them were samples of locomotive fire-box plate, and the others of boiler-plate.

"They were tested for their heat transmitting and steam generating efficiency, with the following results: Allowing the plate of lowest transmitting power to have a value of 100, we have

1	Power of	transmission		100
2	"	"	"	104.4
3	"	"	"	117 7
4	"	"	"	118 8
5	"	"	"	121
6	"	"	"	123
7	"	"	"	123.3
8	"	"	"	141 9
9	"	"	"	144

"It must be distinctly understood that these transmitting powers were measured by the generation of steam under equal and similar conditions. Each plate was subjected to a number of trials; the temperature of the flame to which it was exposed varying, during each series of trials, but a very few degrees from 550 deg Fahr., and the time of evaporation of the water but a few seconds.

"The ratios of values have been calculated according to the tables for such purposes prepared by Dulong. The experiments have been conducted under our direction and immediate supervision by Mr. Charles E. Avery, of Boston, a gentleman thoroughly competent by scientific and practical knowledge for the undertaking of such delicate work.

"In order to discover and avoid all sources of error, the apparatus and method finally adopted for these determinations were first subjected to the test of weeks of most careful experiment.

"To generate an equal amount of steam in equal times and with similar conditions of fuel and draft, boilers made of Nos. 8 and 9 plates would consume *constantly* 40 per cent. less fuel than boilers made of plates Nos. 1 and 2.

"Insomuch, therefore, as their efficiency in the production of steam is vastly greater than that of the inferior plates, the commercial values of these plates will be still greater in proportion. The possibility of a daily economy of 40 per cent. of fuel should induce boiler users to purchase the best plate and boiler plate manufacturers to exercise more care in its manufacture.

"Some of the most considerable variations in evaporative efficiency were found, between plates from the same manufactory.

"No analyses of the iron of the plates have been made, it having been assumed that the comparative presence or absence of slag or glass—a poor conductor of heat—was the chief cause of the determined variations; though, doubtless, carbon and other elements will be found to exercise decided influences. These we propose to determine; and other points of novelty and interest in regard to boiler plates have been decided, which we hope at some future day to give to the public.

"With our method of firing (our application of pulverized fuel to the generation of steam), which almost entirely eliminates other causes of variation, we had found one boiler to have an evaporative efficiency of nearly 60 per cent. more than another. Hence the search for the unknown causes of variation."

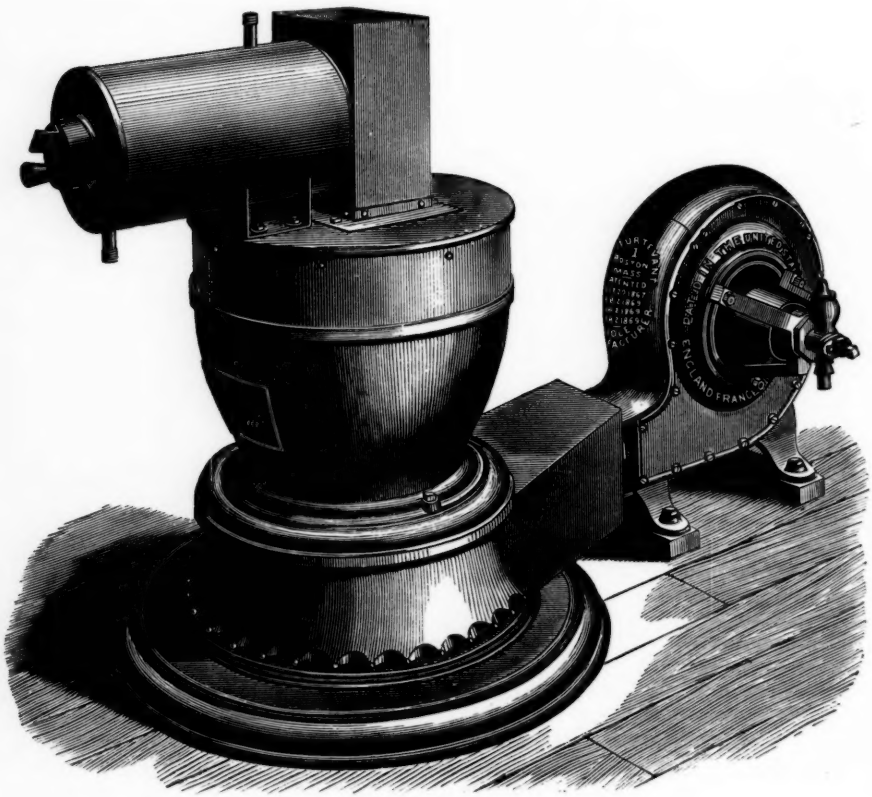
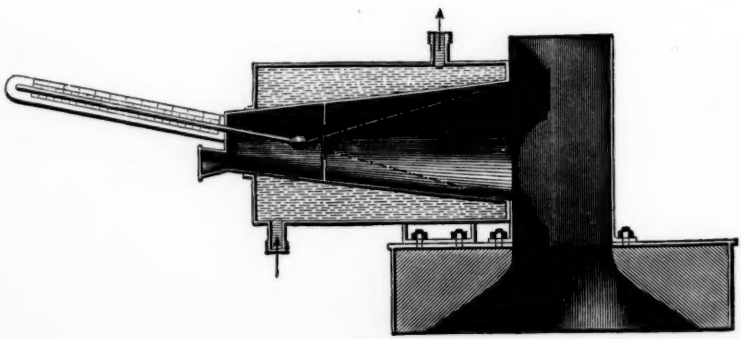
INTERMITTENT FILTRATION.—Mr. Bailey Denton's system of downward intermittent filtration has been tested at Merthyr. The local paper remarks on the subject:—"The public are by this time aware that the system of purification adopted on the land below Troedyrhiw is not irrigation, but a scheme devised by Mr. J. Bailey Denton, the engineer appointed by the Court of Chancery, which he calls intermittent downward filtration. Twenty acres of land have been parcelled out into four panels of equal areas. The whole piece has been drained to a depth varying from 4 to 7 feet, the drains serving the double purpose of collecting and carrying off the subsoil water and the sewage water. The surface of each panel has been carefully prepared for the equal distribution of liquids. The sewage, after being turned on to the land, is left to find its way by percolation or filtration to the drains beneath, the theory being, that in its passage through such a depth of soil, by the time it drops into the drains it has become thoroughly purified—all its offensive solids being left behind and the noxious elements held in solution being decomposed and absorbed by the deodorizing power of the soil, of which the sewage is thus made the incessant fertilizer. The Commissioners first visited the adit of the sewer where the sewage is discharged into the distributing conduits, and half-hourly samples were taken for subsequent analysis. There was only a slight smell as the sewer was opened, and as the sewage flowed over the soil it disappeared—there being an entire absence of odor in walking round the beds. The crops now growing, consisting of turnips, mangolds, cabbages, savoys, Brussels sprouts, broccoli, and winter greens of various kinds, were really of magnificent growth, and excited the greatest interest in the visitors, who mentioned a fact of which it is to be hoped that somebody in this neighborhood may take advantage, namely, that the sewage farms near London not only supply their own neighborhoods with cabbages, but find a market for tens of thousands of them in Birmingham, and even send them so far as Manchester. After traversing the grounds, the Commissioners arrived at the outlet of the subterranean drains, where there was a large volume of the clearest water flowing—an undeniable proof of the efficacy of the system. Samples of the water were taken at half-hourly intervals for analysis. It was said that the laborers on the ground quenched their thirst regularly at this stream, and by way of showing their faith in its purity, many of those present *tasted* the water, which has a very strong chalybeate flavor, and certain indications of the presence of iron. But Dr. Paul has already analyzed it, and says in effect that it would be a boon to the Londoners if they could get drinking water of equal purity. To look at it, one might lay a wager that clearer water never flowed in the Taff."—*Mechanics' Magazine.*

XYLONITE.—Xylonite is a substance of which the chief ingredient is chemically allied to gun-cotton, being formed by the nitric acid upon woody fibre. One of the chief uses to which it is applied is for making impermeable sheeting; and if all that is said about it bears the test of experience, it bids fair to take the place of india-rubber. Different samples of waterproof fabrics vary in substance from a thin transparent tissue up to a thick, strong cloth suitable for water-beds, water-cushions and other articles where strength of fabric is all important. Xylonite has several advantages over india-rubber. It is not affected by a boiling temperature, and can be readily washed in soap and water and ironed like ordinary linen or cotton fabrics. It is not acted upon by oil or grease. Xylonite materials can be made of any color, are considerably cheaper than similar gutta-percha or india-rubber fabrics, can be used again and again, and can be kept in store for any length of time without deterioration.—*London Lancet.*

ASPHALT ROADS IN PARIS.—It is stated that the authorities of Paris are about to give up the asphalt paving, and return to the old-fashioned stones, in consequence of the great expense of keeping up the former. The determination of the Parisians is not encouraging, but then it must be remembered that we are not quite so ready to use our paving-stones for the manufacture of barricades as they are.

THE DECIMAL SYSTEM IN AUSTRIA.—The Austro-Hungarian Government have at last resolved to adopt the decimal system throughout that empire, and that measure is to become legal after the 1st January, 1873.

Apparatus for Measuring the Radiant intensity transmitted by Flames.

Constructed by CAPTAIN JOHN ERICSSON.

PAGE 113.